Implementing Truck-Only Toll Lanes at the State, Regional, and Corridor Levels: Development of a Planning Methodology

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Implementing Truck-Only Toll Lanes at the State, Regional, and Corridor Levels:
Development of a Planning Methodology

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LIST OF ABBREVIATIONS

AADT: Average Annual Daily Traffic

AASHTO: American Association of State Highway and Transportation Officials

ARC: Atlanta Regional Commission

ATA: American Trucking Associations

ATR: Automatic Traffic Recorder

BOT: Build-Operate-Transfer

BTS: Bureau of Transportation Statistics

CARE: Critical Analysis Reporting Environment

CATS: Chicago Area Transportation Study

CST: Cost Saving Threshold

CVHAS: Cooperative Vehicle-Highway Automation Systems

EPA: Environmental Protection Agency

ETC: Electronic Toll Collection

FAF: Freight Analysis Framework

FARS: Fatality Analysis Reporting System

FHWA: Federal Highway Administration

FMCSA: Federal Motor Carrier Safety Administration

GIS: Geographic Information System

GPS: Global Positioning System

GP Lane: General Purpose Lane

Georgia SRTA: Georgia State Road and Tollway Authority

HCM: Highway Capacity Manual

HGV: Heavy Goods Vehicles

HOV: High-Occupancy Vehicle

HOT: High-Occupancy Toll

LCV: Longer Combination Vehicle

LOS: Level-of-Service

LRUC: Lorry Road User Charging

MPO: Metropolitan Planning Organization

NHSTA: National Highway Traffic Safety Administration

OBU: On-Board Unit

PDO: Property Damage Only

PHT: Person-Hours Traveled

PPP: Public-Private Partnership

RMSE: Root Mean Square Error

ROW: Right-of-Way

RP Survey: Revealed Preference Survey

STARS: State Traffic and Report Statistics

SOV: Single-Occupant Vehicle

SP survey: Stated Preference Survey

TAZ: Traffic Analysis Zone

TOT: Truck-Only Toll

TTC-35: Trans-Texas Corridor-35

V/C Ratio: Volume-to-Capacity Ratio

VHT: Vehicle-Hours Traveled

VOT: Value of Time

VMT: Vehicle-Miles Traveled

WCC: Washington Commerce Corridor

SUMMARY

The growing number of trucks traveling on freeways has caused more traffic congestion and increased the likelihood of truck-related crashes. Many transportation agencies are considering a new concept of truck-only toll (TOT) lanes to provide a more efficient and safer freight transportation system. This research develops a methodology for identifying candidate TOT lanes in the freeway system. The modeling of TOT lanes in different geographic applications including individual TOT corridors, a regional TOT network, and a statewide TOT network are derived from the Atlanta Regional Commission (ARC) travel demand model and the Georgia statewide travel demand model. The criteria employed in a geographic information system (GIS)-based screening process to determine feasible TOT corridors and their boundaries/extents include: freeway level of service, truck volumes, truck percentage of total freeway flow, truck-related crashes, and truckers' willingness to pay. The research also presents the process for determining various toll rates that achieve the objective of maximum revenue generation, an acceptable level of service, a TOT lane utilization of greater than 50%, and a truck diversion rate from local roads to the TOT lanes.

In addition, this research addresses issues of assessing the engineering design of TOT lane placement and the performance measures of using either mandatory or voluntary TOT lanes. The level of through truck trips, the relocation of HOV lanes, and the acquisition of right of way are incorporated into the feasibility of building inside or outside TOT lanes. Based on the modeling results of through truck traffic from the entire regional interstates, this research recommends a threshold value for inside TOT lanes of more than 50% through truck volumes with direct access to major freight generators. Outside TOT lanes are appropriate for less than 30% through truck volumes. This research also examines freeway performance under two scenarios -- adding general

purpose lanes or building TOT lanes with both mandatory and voluntary use. Furthermore, performance measures are assessed for various levels of truckers' values of time (VOT) in order to determine the level of sensitivity of the results to this important input variable.

Finally, this research addresses the strategies for critical issues associated with the planning, design, and operation of TOT lanes and presents TOT planning guidance based on the modeling results of building TOT lanes in the Atlanta regional freeway system. This guidance is a resource to assist transportation agencies better understand TOT lane projects and help achieve the goals of TOT lanes to relieve traffic congestion, reduce truck-related crashes, and generate additional revenue to fund TOT projects.

CHAPTER 1

INTRODUCTION

1.1. Importance of Truck Movements

The movement of freight in the United States, indeed, any country, is an important component of the nation's economic vitality. Throughout history, cities have been located where flows of commerce intersect, whether this was along coasts, near major trade routes, or at the end of high capacity transportation facilities. Since the early 1900's, trucks have played an increasingly important role in the U.S. economy, so much so that they carry a large percentage of the nation's freight tonnage. When these trucks occupy a road at the same time as passenger vehicles, there is a potential for greater levels of congestion as well as an increased level of truck-car crashes. Some statistics on the growth of truck movements indicate the challenge facing many states and metropolitan areas.

From 1995 to 2005, according to U.S. DOT statistics (BTS 2006), the number of registered heavy trucks has increased by 26% from approximately 6.7 million to 8.5 million; annual truck vehicle-miles traveled (VMT) on U.S. highways has grown by 25% from 178 billion to 223 billion. In comparison, the number of registered passenger cars grew by 6% from 128.4 million to 136.6 million and passenger car VMT grew by 17% from 1.438 trillion to 1.69 trillion during the same time period. In 2005, heavy truck VMT accounted for 7% of total highway VMT despite the fact that registered heavy trucks accounted for only 3% of all registered motor vehicles. Furthermore, from 1995 to 2004 truck ton-mile shipments increased by 27% from 1.034 trillion to 1.315 trillion, which was close to the 28% ton-mile growth rate of rail from 1.317 trillion to 1.684 trillion.

According to Federal Highway Administration (FHWA) forecasts (FAF 2005), total truck tonnage carried will increase by 83% between 1998 and 2020, which is higher than the estimated 63% tonnage growth of rail. The annual growth rate of truck VMT from 1998 to 2020 will be 3.2%, which is also higher than the 1.8% annual growth of the passenger car VMT.

National Highway Traffic Safety Administration (NHSTA) statistics (FARS 2005) indicate that fatal crashes involving passenger cars decreased 19% between 1995 and 2005 from 30,940 to 25,029, while fatal crashes involving heavy trucks increased 10% from 4,472 to 4,932 during the same time period. According to FHWA reports (FMCSA 2007), fatal crashes involving passenger cars per 100 million vehicle miles traveled dropped 23% from 2.2 to 1.7, while fatal crash rates involving heavy trucks decreased 12% from 2.5 to 2.2 per 100 million vehicle miles traveled over the same time period, as shown in Figure 1-1. In 2005, fatal crashes involving heavy trucks accounted for 12% of all traffic fatalities even though registered heavy trucks accounted for only 3% of all registered motor vehicles.

Because of the expected growth, heavy trucks sharing the highways with passenger cars could cause more traffic congestion and increase the likelihood of truck-car crashes. In response, many transportation officials are considering a new concept of truck-only toll (TOT) lanes aimed at managing highway operational conditions and providing a safe and efficient transportation system. TOT lanes are one type of a managed lane strategy that provides tolled lanes for commercial vehicles. Shifting most heavy trucks from the mixed traffic flow on general purpose lanes could stabilize traffic stream and improve mobility as well as safety, particularly for trucks carrying hazardous material and dangerous goods. (TOT lanes are usually designed with barriers to separate them from general purpose lanes. Additionally, to reduce the truck-car conflicts at weaving or merging sections, exclusive ramps or interchanges for truck access and egress to freeways might be built).

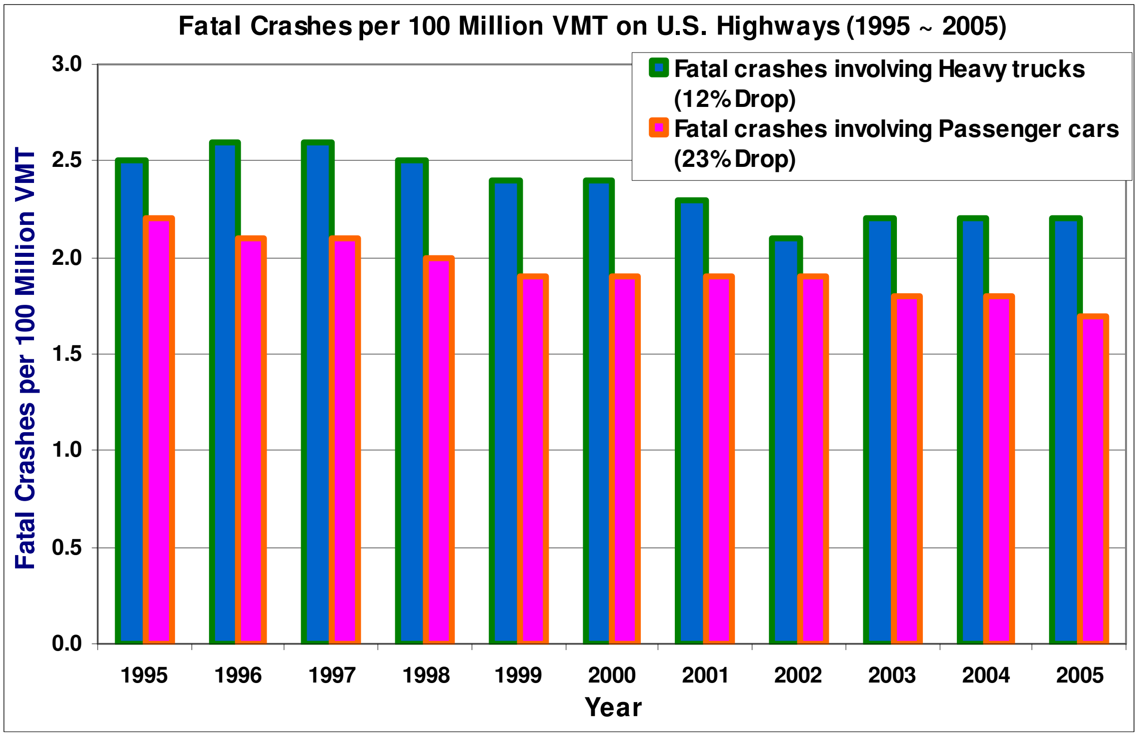


Figure 1-1: Fatal Crashes Involving Heavy Trucks and Cars from 1995 to 2005

Source: FMCSA, 2007

1.2. Research Objectives

The objective of this research is to develop and test a methodology to assess the feasibility of TOT lane candidates at corridor, regional, and statewide levels. The planning methodology is applied to examine the feasibility of TOT lanes in the state of Georgia and to assess the benefits from candidate TOT lanes. Based on the analysis, this research identifies combinations of feasible TOT lanes for individual interstate facilities, the Atlanta regional interstate system, and the Georgia statewide interstate system. Planning guidance for the implementation steps of TOT lanes is also developed.

1.3. Planning Considerations

Several critical questions concerning TOT operations, political factors, and financial viability need to be fully understood when planning TOT lanes. This section introduces following questions that are important elements of this research effort: (1)

what are the important characteristics of planning TOT lanes? (2) what determines the feasibility of TOT lanes? and (3) what is the most successful implementation process for TOT lanes? Results from this research will provide a more detailed answer to each of these questions.

1.3.1. Important Characteristics of Planning TOT Lanes

The important characteristics of planning TOT lanes will likely include answering the following questions: (1) is there enough truck travel demand to implement TOT lanes? (2) does the trucking industry support or oppose TOT lanes? and (3) what are the benefits of implementing TOT lanes?

1.3.1.1. Sufficient Truck Travel Demand

Potential truck traffic demand is a key consideration for TOT lanes, not only to justify their construction, but also to provide sufficient revenues toward their operation. Truck trips traveling on TOT lanes primarily consist of through traffic that originates and terminates outside the corridor, and longer distance local traffic that originates or terminates within the corridor. In general, truck traffic with fixed delivery schedules, penalties for arriving late, and high-value freight movements would likely have a higher demand for TOT lanes; freight movements with low travel time sensitivity would likely seek routes that avoid the TOT lanes. In addition, considering the benefits of travel time savings and reduced fuel consumption, truckers would likely prefer to use TOT lanes over heavily congested routes in urban areas. The importance of predicting TOT lane demand is clearly something that will have to be reflected in the TOT planning process.

1.3.1.2. Trucking Industry Support

One of the key factors in planning TOT lanes is to gain the support from the trucking industry. In general, the trucking industry has opposed the use of tolls on existing highway systems. According to the American Trucking Associations (ATA), historical average profit is 2 to 4 cents/mile for the trucking industry (ATA 2005). This value is usually lower than the toll rates estimated by toll authorities, which means a net loss for many trucking firms using that facility. The Reason Foundation (Peter et al. 2002) proposed that truckers would agree to pay a toll up to one-half of the cost savings from the use of the TOT lanes. Truckers may use TOT lanes if they recognize that the benefits of travel time savings and trip reliability are greater than the tolls they pay. If toll fees are higher than the economic benefits of using TOT lanes, then truckers would likely select alternative routes (if they are available) resulting in lower TOT volumes.

The willingness of truckers to use TOT lanes suggests that a sensitivity analysis of toll levels and price elasticity of demand needs to be further studied to examine truckers' willingness to pay tolls for using TOT lanes. Also, a mandatory or voluntary use strategy of TOT lanes needs to be considered in the development of TOT Lanes.

1.3.1.3. Benefits

The benefits of implementing TOT lanes will likely relate to freeway operational efficiency, safety, economic development, and potential reduction in environmental impacts. For operational efficiency, congestion levels on general purpose lanes and parallel routes could be improved if trucks shift to the TOT lanes. General purpose lanes will have a better level of service, higher travel speed, and less delay during peak periods if a substantial number of trucks are willing to use TOT lanes. Regarding safety benefits, since trucks and cars are separated by barriers, truck-car crashes will be reduced. Economic benefits to the trucking industry relate to the increased freight productivity from travel time savings. Increased trip reliability and reduced transportation costs of fuel consumption due to severe congestion or delay caused by truck-car accidents could also benefit individual truckers. With respect to environmental benefits, if stop-and-go traffic conditions decrease as congestion is improved on the general purpose lanes, air pollution emissions from slowed or stalled cars and trucks will be reduced. However, a more detailed analysis would have to be conducted of the potential increase in diesel emissions that might occur if more trucks are attracted to the corridor.

1.3.2. Feasibility of Developing TOT Lanes

The following sections discuss some of the factors that will likely affect the feasibility of developing TOT lanes: (1) what are the significant TOT-related impacts on the existing interstate system? (2) can TOT lanes be self-financing from toll revenues? and (3) what are the legislative restrictions to TOT lanes?

1.3.2.1. Impacts on Existing Interstate system

Freight bottlenecks on highways can be improved by shifting trucks from congested general purpose lanes to TOT lanes. However, congestion levels, travel speeds, delays, incidents, and emissions on the existing interstate system could also be improved. Some possible negative impacts of building TOT lanes need to be considered, depending on the shifts in truck traffic. For example, more trucks could be attracted to use the TOT lanes or more vehicles might travel in the corridor because of better levels of service. The increase in vehicle-miles traveled could increase air pollution. Also, engineering concerns need to be addressed such as the difficulty to obtain right-of way to build TOT lanes and to construct exclusive ingress/egress interchange ramps as well as the possible need to relocate existing high-occupancy vehicle (HOV) lanes to place TOT lanes, depending on freeway design. Any proposed planning methodology would have to describe how such impacts can be determined.

1.3.2.2. Self-Financing Opportunity

The project costs of TOT lanes can be financed from three major funding resources: federal grants, state and local funds, and toll revenues. Surveys have shown that the public would prefer using toll revenues collected from road users instead of taxpayers' money (federal and state/local funds) to finance TOT lanes (David et al.

2005). The trucking industry would prefer using federal and state/local funds instead of tolling existing toll-free interstates to finance TOT lanes. In general, successful self-financing is mainly dependent on whether TOT lanes can generate sufficient toll revenues to support their construction and operation/maintenance costs. The opportunities of self-financing through toll revenues are affected by the toll rates and truck travel demand. The trade-off between toll rates and demand is such that higher toll rates might cause truck diversion to other "free" routes and result in insufficient revenue generation. The TOT planning methodology will likely have to examine the financial implications of different TOT operations strategies.

1.3.2.3. Legislative Restrictions

Two key federal laws that affect the feasibility of tolled highways and heavy truck operations includes: (1) the SAFETEA-LU in 2005 (FHWA 2005) authorized states to impose tolls on existing interstate highways for constructing interstate highways or managing congestion, and (2) the Intermodal Surface Transportation Efficiency Act (ISTEA) law in 1991 prohibited states from allowing longer combination vehicles (LCVs) on the interstate system at a gross vehicle weight over 80,000 pounds and overall length of the cargo carrying vehicle exceeding 57 feet (FHWA 2004).

Currently, there is no legislation that regulates whether states implement mandatory or voluntary use of TOT lanes. Therefore, state DOTs need to choose mandatory or voluntary use of TOT lanes based on an assessment of financing viability and support from the trucking industry. Also, whether to allow LCVs such as double or triple trailers to travel on TOT lanes needs to be decided, which would require a different engineering design such as wider lane width and stronger pavement structure to accommodate trucks of bigger size and weight.

In addition to federal laws, many states have their own laws regarding truck operations, and in some cases has the road network is operated. For example, enforcement responsibilities are often defined by state statute. The uses of toll revenues or even entering into public private partnerships are also issues subject to state enabling legislation.

It is likely that one of the first steps in a TOT planning process will be an analysis of the legal and institutional barriers that currently exist.

1.3.3. Implementation Process of TOT Lanes

The process of implementing TOT lanes includes planning, design, and operations. Key elements associated with these steps include the following: (1) identify the needs for improvements, (2) evaluate the engineering and design for the selected corridor, and (3) examine the level of public acceptance of operation policies.

1.3.3.1. Selection of TOT lane Candidates

The first step is to identify candidate TOT lanes using evaluation criteria such as congestion levels, truck travel demand, truck trip characteristics, and crashes involving trucks. Other evaluation criteria could include locations of major freight generators and acquisition of right of way (ROW). Therefore, an ideal TOT lane candidate corridor may show heavy congestion, high truck volumes, high truck crashes, high proportion of through or long-haul truck trips, main access to seaports, airports, rail yards, and large warehouse and distribution centers, and available right of way to build additional lanes. This research will identify the most appropriate criteria for the Georgia case.

1.3.3.2. Evaluation of the Extent of TOT Lane Segments

Currently, most studies identify TOT lane segments based on the evaluation of freight bottlenecks to alleviate congestion, improve safety, and increase freight productivity. Also, the extent/boundary of TOT corridors is usually decided based on agency policy or the connectivity of system interchanges. However, not all segments along a corridor need to provide protected truck movement if different congestion levels are present. For example, if a corridor experiences severe congestion on only the first half section because of large truck volumes, then TOT lanes built through this whole corridor could have a low usage rate on the last section (assuming trucks are allowed to leave the TOT lanes at specified locations). Truckers are unlikely to pay tolls to use TOT lanes where there is no benefit in travel time savings. Therefore, in order to optimize TOT lane utilization and economic investment, determining the appropriate extent/boundary of TOT lanes needs to be addressed. This issue will be more critical when building TOT lanes at the regional or statewide level because of the interaction among multiple corridors.

1.3.3.3. Mandatory or Voluntary Use

In many case, sufficient revenues might not be generated if trucks are not required to use the TOT lanes. In such a case, pricing strategies would be a key factor in financing TOT lanes. Trade-offs between revenue generation and travel operating efficiency have a high degree of sensitivity to toll rates. Most studies have determined toll rates based on an adopted average rate or criteria of maximum revenues and acceptable travel conditions such as level of service C or D. However, the utilization rate of a TOT lane to justify transportation investment and the expected truck diversions used to evaluate impacts to local traffic condition are not often incorporated into the selection of toll rates. For example, a higher truck diversion from TOT lanes to alternative free routes would increase local traffic congestion, truck-related accidents, and air pollution. An optimum toll rate should be evaluated based on these criteria simultaneously.

1.4. Research Methodology

Figure 1-2 shows the methodology used in this research. The initial step in the research was to obtain data on vehicle counts, truck classification, and truckers' willingness-to-pay. These data, obtained from existing data sources, were used to validate the base year 2005 Atlanta Regional Commission (ARC) travel demand model. In addition, data on truck-related crashes were used to identify locations of high crashes involving trucks. Chapter 4 will discuss in greater detail some of the limitations of the data used in this research. In general, however, these limitations relate to the small number of data collection locations available in the Atlanta region (only 11 automatic traffic recorder devices collect data on truck volumes). In addition, truckers' willingness-to-pay stated preference surveys were used only on the I-75 corridor, and thus this research assumes that such willingness-to-pay is similar for other interstates in the state.

Once the model has been validated, screening criteria for identifying feasible TOT corridors and segment boundaries are identified. As shown, these screening criteria relate to such things as low levels of service currently on the freeway, high truck volumes and percentages (both including heavy trucks and medium trucks), and high truck-related crashes. Given the truck volumes expected on a particular segment, the research also examined the feasibility of a TOT lane given different levels of truckers' willingness-to-pay as compared to travel time savings. Design considerations are also included in the feasibility assessment by examining the level of through truck trips, right of way availability, and the ability to relocate high occupancy vehicle lanes, if needed.

The next step was to determine the toll rates for the segment that maximizes the revenues generated, providing an acceptable level of service, having a TOT lane utilization of greater than 50%, and a truck diversion rate from local roads to TOT lanes greater than 0%.

All of the above information is then used in the next step to identify feasible TOT lane candidates based on different scenarios of adding general purpose lanes, building new TOT lanes, implementing mandatory TOT lanes, or using voluntary TOT lanes based on their operating performance. Performance measures are assessed for different levels of value of travel time in order to determine the level of sensitivity of the results to this important input variable.

The final step provides research conclusions and produces planning guidance on implementing TOT lanes at different geographic scales.

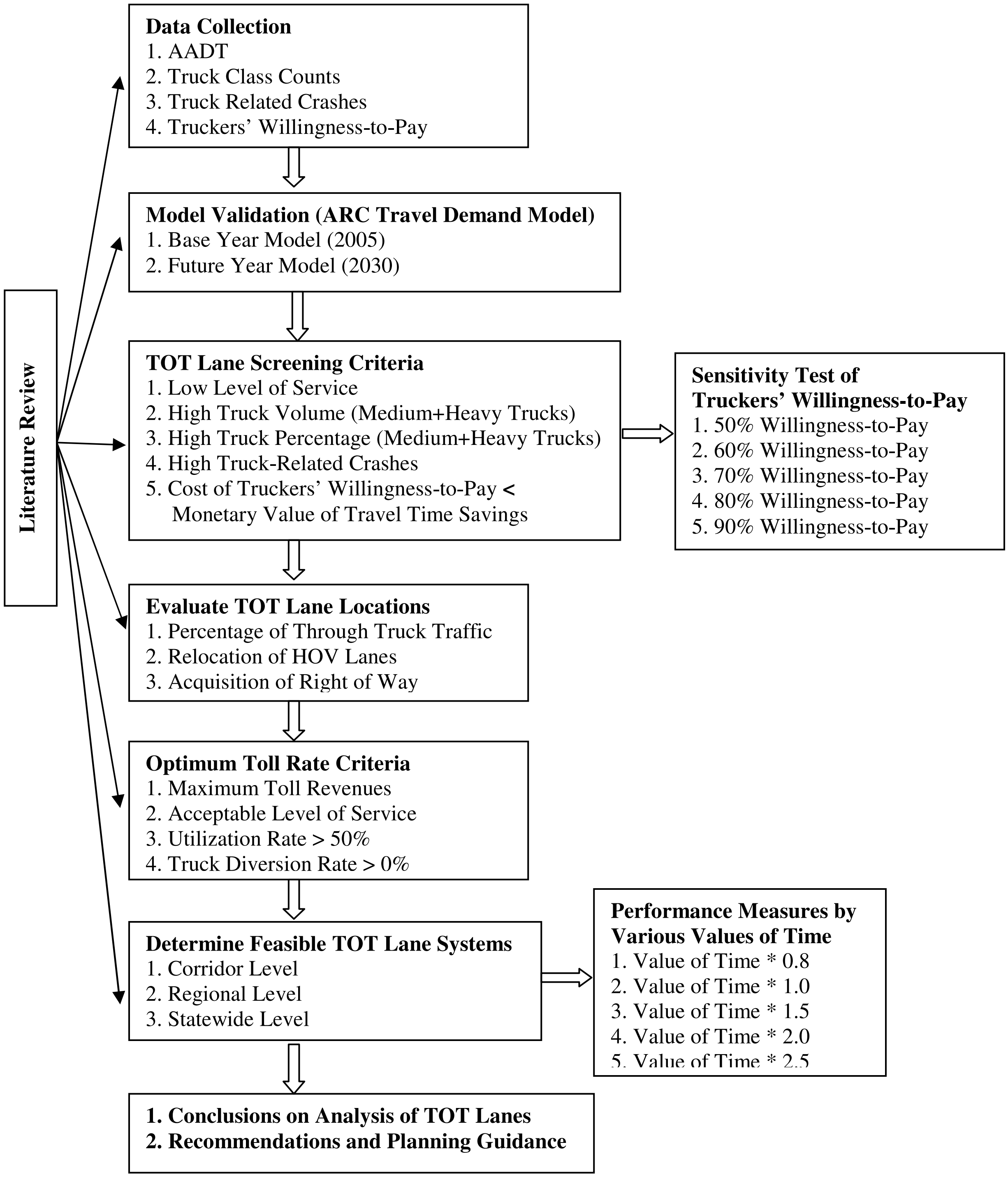


Figure 1-2: Framework of the Research Methodology

1.5. Research Contributions

This research contributes to the planning process of TOT lanes in the following ways. First, this research identifies the key factors and variables that affect the feasibility of TOT lanes, such as truckers' willingness-to-pay, the level of truck diversion, TOT lane utilization, and the percentage of through truck tips. Second, this research develops methodologies to identify feasible TOT lane candidates by incorporating these key factors. The methodologies use different sensitivity tests to show their possible application to other metropolitan areas and states with similar truck trip characteristics. Third, this research illustrates the application of planning methodologies for implementing TOT lanes. Finally, this research generalizes specific results to the transportation community and develops planning guidance for TOT lanes. This guidance will provide traffic engineers with implementation steps for TOT lanes.

1.6. Dissertation Outline

This dissertation is organized into seven chapters.

Chapter 1 – Introduction: Chapter 1 has provided an overview of TOT lanes, and introduced the research statement and approach.

Chapter 2 – Literature Review: Chapter 2 provides an overview of planned or proposed TOT lanes in the United States and Europe. This chapter also examines issues and opportunities regarding the implementation of TOT lanes, which incorporate political, financial, engineering, safety, and environmental challenges. In addition, factors and variables such as revenue generation, measures of operational efficiency, utilization, and truck diversion that affect the feasibility of TOT lanes are identified. The literature review also summarizes previous methodologies of assessing TOT lanes such as screening approaches of TOT lanes and selection criteria of optimum toll rates.

Chapter 3 – Data: Chapter 3 discusses the datasets employed and different geographic levels applied in this research. This chapter utilizes the data collected from

Georgia DOT existing databases to proceed with the model runs of future truck travel demand and performance measures of TOT lanes.

Chapter 4 – Methodology: Chapter 4 describes the method of model validation and uses the results obtained from the validated travel demand model to analyze performance measures of TOT lanes. In addition, several assessment criteria are developed to determine the candidates for TOT lanes, placement of TOT lanes, and selection of optimum toll rates. Sensitivity tests for different levels of truckers' willingness-to-pay and truckers' values of time are conducted to reflect the application of the methodology to other areas. Truckers' willingness-to-pay is defined as how much more toll costs truckers are willing to pay for better traffic conditions such as a reduction in travel time. A stated preference (SP) survey is used to measure truckers' values of time. Truckers' values of time ($/hr) measured as trade-offs between toll costs ($) and travel time savings (hr) reflect various truck types (for-hire or private) and trip characteristics (long-haul or short-haul), a more accurate estimate than a single value of time for all truckers. To determine the feasible TOT lanes at different geographic levels, an appraisal scheme is proposed to determine the best alternatives. Modeling scenarios of building general purpose lanes or TOT lanes and mandatory or voluntary TOT lanes are assessed in the scheme.

Chapter 5 – Research Results: Chapter 5 presents the results of feasible TOT lane candidates for individual corridors, the Atlanta region, and at the Georgia statewide level. Due to the limitation that the statewide travel demand model cannot analyze detailed truck trip origins and destinations within the same county, TOT corridor candidates are identified at the statewide level. Performance measures such as revenue generation, level of service, and travel time savings under different sensitivity tests and modeling scenarios are compared and discussed in geographic levels of individual corridors and regional network.

Chapter 6 – Planning Guidance: Chapter 6 proposes strategies to deal with issues related to the implementation of TOT lanes. Additionally, a planning guidance of implementation steps for TOT lanes is developed based on the study results.

Chapter 7 – Conclusions and Recommendations: Chapter 7 summarizes the contributions and findings of this research and offers recommendations for future research.

CHAPTER 2

LITERATURE REVIEW

The literature on managing truck use of freeway lanes in general purpose and TOT lanes, specifically, is very limited. Given the relative newness of the TOT concept, this is not surprising. However, some articles have been written on truck-only lanes, and a small number of projects have actually been implemented. This chapter reviews this literature and identifies those factors that have been identified that affect the feasibility of TOT lanes and the methodologies that are employed to assess TOT lanes.

2.1. Planned or Proposed TOT Lanes

Currently there are no existing TOT lanes in the United States and Europe. Thus, historical data that demonstrate the performance of TOT lanes on interstate highway systems are lacking, particularly with respect to truck traffic in congested urban corridors. However, the concept of truck-only toll lanes (or toll truckways) has been studied in a few locales primarily as a means of relieving traffic congestion, improving safety, and reducing air pollution.

2.1.1. United States

In the United States, only very few states have built truck-only lanes (or truckways), with the best examples being in California, Louisiana, Massachusetts, and New Jersey. Some states, such as California, Florida, Georgia, Missouri, Texas, Virginia, and Washington, are planning to develop TOT lanes in selected corridors, regions, or on statewide networks.

2.1.1.1. California

California (CALTRANS 2006) has two truck-only lanes on I-5 in Los Angeles County (2.43 miles) and I-5 in Kern County (0.35 miles). These truck-only lanes are barrier separated from the general purpose lanes.

In 2001, the Southern California Association of Governments (SCAG 2004) in Los Angeles proposed regional toll truckways on the SR-60, I-710 and I-15 freeways to alleviate congestion and improve air quality in the region. Two elevated truck lanes in each direction would be added from the Ports of Long Beach and Los Angeles northeast to Barstow. The design capacity was 800 vehicles per lane mile per hour. The cost of the 142-mile tolled truckway proposal was $16.5 billion (2001 dollars). Toll rates would be varied based on the time of day and level of congestion. Toll revenues from SR-60 were expected to cover 30% of the development costs of SR-60 at a toll rate between 35 to 70 cents/mile. This 30% coverage did not meet the regional truckway policy that such facilities should be self-financing from toll revenues over a 30-year financing period based on tolls ranging from 38 to 80 cents/mile (an average rate of 56 cents/mile). Public-private partnerships (PPP) are encouraged as part of this policy to help speed the construction of the toll lanes. SCAG would require longer combination vehicles (LCVs) to use the toll truckways, but other trucks would have the option to choose between toll truckways or free general purpose lanes. The trucking industry supported this proposal.

2.1.1.2. Florida

In 2002, the Florida DOT conducted a study to evaluate the feasibility of truckways on Florida's state highway system (FDOT 2002, Stephen et al. 2003). Based on the criteria of the percentage of truck volume, car-truck crash rates, low level of service, and available right of way, the study selected potential truckways for six corridors including: I-95 from Miami to Titusville, I-95 from Daytona to Jacksonville, I-75 from Naples to Ft. Myers, I-4 from Tampa through Orlando to Daytona, I-75 from Venice to the

Florida/Georgia State Line, and I-10 from Lake City to Jacksonville; and three areas of Miami, Tampa, and Jacksonville. Concrete barriers would be used to separate truckways from general purpose lanes. Because the conceptual design required a median in these corridors, the study suggested that truckways be built in the median only if the distance between two interchanges was long enough to avoid exit and entrance weaving maneuvers. Truckways would be financed by bonds that could be issued by state or private investors with long-term authorization agreements and repaid through tolls. Florida proposed that LCVs would have to use the toll truckways; for other trucks, it would be an option.

2.1.1.3. Georgia

In 2005, Georgia's State Road and Tollway Authority (SRTA) conducted a study of TOT facilities in the Atlanta region (Georgia SRTA 2005, Meyer et al. 2006). A regional TOT network for the target year 2030 was proposed to improve safety, reduce congestion, and create reliable trips for both trucks and cars in the metro Atlanta area. This study modeled three scenarios for TOT lanes: (1) add two voluntary TOT lanes in each direction on I-75 (north and south of I-285), on I-85 (north of I-285), and on I-285 west between I-75S and I-85N, (2) the same as scenario 1, except allowing light-duty trucks to share HOV lanes inside I-285 during off-peak periods from 10 a.m. to 3 p.m. with tolls, and (3) convert planned HOV lanes on I-75, I-85, and I-285 into voluntary TOT lanes. Scenario 3 was recommended because it generated the greatest annual revenue of \$198 million, incurred the lowest construction cost of \$578 million, produced the greatest travel time savings, and created the greatest congestion reduction on the general purpose lanes.

This study assumed a value of time of \$18/hr for light trucks and \$35/hr for heavy trucks to estimate toll rates. Toll rates would be adjusted according to the congestion level in the TOT lanes to limit excess truck volumes and maintain TOT lane performance (a minimum level of service D). Public-private partnerships would be considered as a financing approach under Georgia's public-private partnership legislation. Truckers would not be required to use the TOT lanes under the proposal. The trucking industry supported the concept of the TOT lanes only if truck use of these lanes was voluntary. They also expected LCVs to be allowed in the TOT lanes.

In 2006, the Georgia DOT undertook a I-75 northwest corridor study to improve safety and reduce congestion on the interstate roads in Cobb and Cherokee counties (GTP 2007). This multi-modal corridor study is considering several types of managed lanes such as high occupancy vehicle (HOV) lanes, high occupancy toll (HOT) lanes, express bus or bus rapid transit (BRT), and truck-only toll (TOT) lanes. The 15-mile TOT lanes with two lanes in each direction would be barrier-separated from inside general purpose lanes and outside express toll lanes (ETL). Two scenarios including voluntary use of TOT lanes and mandatory use for through truck trips in this corridor were proposed (Georgia SRTA 2006). Toll rates on TOT lanes in the projected year of 2030 were estimated as 15 cents/mile during off-peak periods to 80 cents/mile during peak periods. They would vary by time of day and travel direction. This corridor would have the first TOT lanes in Georgia and be the most promising corridor to raise toll revenues because it is one of Atlanta's most congested highways and a primary truck route with trucks accounting for 30 percent of traffic volume. Public-private partnerships were to be part of project financing.

Currently, the Georgia DOT is working on an estimated "Statewide Truck Lanes Needs Identification Study" to identify potential corridors for truck-only lanes on the state highway system (GDOT 2007). Implementation strategies for candidate truck-only lane corridors will be proposed, particularly in the metro Atlanta area and the port of Savannah, both of which experience a lot of through and local truck traffic.

2.1.1.4. Illinois

In 2003, the Chicago Area Transportation Study (CATS), the metropolitan planning organization (MPO) for the Chicago region, proposed dedicated truckways to improve the performance of heavy truck freight movements in the Chicago metropolitan area (Rawling et al. 2003). Depending on available rail right of way, truckways could be built on existing railroad property either adjacent to the tracks or elevated. The truckways would connect important intermodal rail terminals to I-90 and I-294. A cooperative vehicle-highway automation systems (CVHAS) project analyzed four truckway alternatives with the results showing benefit/cost ratios from 2.45 to 5.15 (Steven et al. 2004). The recommended alternative was to build a truckway with one lane in each direction for all trucks before 2015. As truck volumes increased, the truckway would be upgraded to an automated highway open only to trucks with ITS technology. The automated operation would include automated driving, automatic speed, and automatic spacing control. It was expected that this CVHAS technology would reduce congestion, improve travel time, reduce crashes, and decrease pollutant emission.

2.1.1.5. Louisiana

In 1998, New Orleans built the Clarence Henry Truckway to separate trucks from local traffic and serve as truck access routes to the Port of New Orleans (City of New Orleans, 2005). The 3.5-mile, two-lane truckway is the main transportation artery between I-10 and New Orleans' Uptown River Terminals. It is not physically separated from local traffic.

2.1.1.6. Massachusetts

In 1993, the South Boston truck-only bypass road was constructed, to remove truck traffic from the local streets near I-93 (FHWA 2003). The short, 1.5-mile road has one lane in each direction, which is not physically separated. This project was developed as a truck road to serve the large number of trucks that were expected for the Central Artery project, especially the construction of the new Boston harbor tunnel. After the tunnel was constructed, the road was to be used as a truck access road to the port in order to keep trucks out of the main construction project.

2.1.1.7. Missouri

In 2006, the Missouri DOT proposed to construct two inside truck-only lanes in each direction on I-70. Dedicated interchanges and ramps connected with major arterials were to be considered at limited access points. Voluntary or mandatory tolls for trucks are under evaluation (Kathy Harvey 2006).

2.1.1.8. New Jersey

New Jersey's turnpike includes a 33.5-mile section of car-only lanes on the inner roadways and car-truck shared lanes on the outer roadways north of exit 8A. In 1998, Newark, New Jersey proposed a Portway project (NJDOT 2003) to reduce truck congestion and improve efficiency of freight movement in northeastern New Jersey. The $700 million Portway project would build 20-mile truck-only toll lanes with two lanes in each direction from Port Newark/Elizabeth to Little Ferry in Bergen County. Portway is a short-distance, local highway, not an interstate highway. To provide efficient access to Port Newark/Elizabeth and remove trucks from local roads, trucks would be restricted to travel on the Portway truck-only lanes and Turnpike car-truck shared lanes.

2.1.1.9. Texas

In 2005, the Texas DOT proposed the Trans-Texas Corridor-35 (TTC-35) to improve congestion, reliability, safety, and air quality in the I-35 corridor (TxDOT 2005). TTC-35, a north-south multi-modal corridor parallel to I-35 from north of Dallas/Forth Worth to the Texas/Mexico border, will include rail lines, car-only lanes, and truck-only lanes. TTC-35 with two truck-only toll lanes in each direction would restrict trucks to drive only in the designated lanes. Trucks and cars would be separated by a median. The costs of the approximately 600-mile TTC-35 truck lanes are expected to be $7.2 billion.

Public-private partnerships would finance the development of the 50-year projects that would constitute the entire corridor project (Antonio 2005). Truckers would voluntarily use truck-only toll lanes based on the trade-off between toll costs and time savings. LCVs would be allowed to use TTC-35 to reduce truck traffic on I-35. The trucking industry supported the project. As of 2007, this project is still in environmental review.

2.1.1.10. Virginia

In 2004, Virginia proposed a "STAR" truck-only toll lane plan to improve safety and reduce congestion along 325 miles of I-81 throughout the Shenandoah Valley (STAR 2003). I-81, one of the busiest truck corridors in the U.S., was designed for a maximum capacity of 15% truck traffic, but truck traffic has grown to be 30-40% of total traffic volumes. Two inside truck-only toll lanes would be added in each direction. There would be two to four outside tolled general purpose lanes in each direction. Trucks and cars would be separated by rumble strips or grassy median areas. Exclusive exit/entry ramps (fly-over ramps) at main truckway interchanges would be provided. A boothless electronic tolling system would be designed to improve smooth traffic flow. A public-private partnership under Virginia's Public-Private Transportation Act (PPTA) would be used to accelerate the construction of truck lanes. The proposed toll rate of 27 to 37 cents/mile is anticipated to pay at least half the project cost of $13 billion over a 40-year financing period. The remaining debt would be repaid by federal and state funds.

Local governments in the Shenandoah Valley, however, preferred rail alternatives rather than the STAR plan to reduce truck traffic on the I-81, because they believed truck-only toll lanes would attract more truck traffic and cause negative environmental impacts such as increased air pollution and noise as well as damage natural resources. Virginia's trucking association also opposed the toll truck lane plan because it requires mandatory truck use and does not allow LCV access.

Virginia DOT has recently considered adding one or two general purpose lanes in each direction where needed instead of constructing separate truck-only lanes on I-81 (VDOT 2007).

2.1.1.11. Washington State

In 2004, Washington State conducted a Washington Commerce Corridor (WCC) study to provide additional capacity for truck and car traffic (WSDOT 2004). The multi-modal WCC, similar to Texas's Trans-Texas Corridor, included railroads, car-only roads, and truck-only roads. WCC would serve as an alternative to and bypass routes for the congested I-5. The entire 280-mile north-south corridor from the Canadian border to the Oregon border would cost \$42 to \$50 billion, while the toll truckway with two lanes in each direction would cost \$9 to \$11 billion. Truck tolls of 15, 30, 45 and 60 cents/mile were modeled based on assumed diversion rates of truck traffic from I-5 of 25%, 50%, 75%, and 100%. To be self-financing, at least 50% truck traffic from I-5 needs to be attracted to the WCC, representing a toll rate of 30 cents/mile. Two segments (I-90 to Chehalis and Chehalis to the Oregon border) are expected to produce promising toll revenues because of high through truck traffic. Public-private partnerships would be considered to finance the completion of these 30-year projects. The trucking industry supported the truck corridor and anticipates it could lower their transport costs along the I-5, increase productivity, and improve service to their customers, compensating for the cost of the tolls.

2.1.2. Europe

Currently, no European country has truck-only lanes or TOT lanes on its autobahns/motorways. There is no physical separation between trucks and cars on European motorways. Trucks are restricted to stay in the right lane unless passing a slower moving vehicle. However, mandatory tolls for trucks traveling on mixed-flow motorways have been implemented by several counties such as Austria, Germany, Switzerland, and United Kingdom. Electronic toll collection (ETC) systems identify trucks on the tolled motorways. The truck toll system seeks to improve truck productivity, contribute to highway finance, and reduce air pollution.

2.1.2.1. Austria

Austria mandated commercial vehicles over 3.5 tons to pay tolls based on the distance traveled on its autobahns. A vignette (toll sticker) was used for cars and trucks driving on the autobahns (Kapsch 2004). In 2004, Austria initiated a microwave toll system by installing GO boxes inside trucks to detect their locations and automatically record the distance driven on the autobahns, but this system does not use global positioning system (GPS) technology. It was estimated that 600 million Euros in toll revenues would be created by 100,000 Austrian and 300,000 foreign trucks per year traveling on the autobahns (Deutsche Welle 2004).

2.1.2.2. Germany

In 2005, Germany implemented mandatory tolls for heavy trucks over 12 tons traveling on the 12,000-km autobahn network (Federal Ministry of Transport 2007). The heavy goods vehicles (HGV) toll collection system uses mobile telecommunications and internet to monitor trucks equipped with GPS-based on-board units (OBU) and calculate the distance trucks travel on the autobahn (distance-based charge). Toll rates that range from Euro \$0.09 to \$0.14 per kilometer are dependent upon the emission categories and the number of axles, as shown in Table 2-1. Three emission categories of A, B, and C based on European emission standards (Euro 1 ~ 5) for heavy-duty diesel engines and two axle classes of less than four axles and four or more axles are used to determine the toll rates. Toll revenues generated from the Germany HGV tolling system were 2.87 billion Euros in 2005 and increased to 3.08 billion Euros in 2006.

Table 2-1: Germany's HGV Toll Rates (in Euros)

Emission Category	3 Axles or Fewer	4 Axles or More
Category A (Euro 5)	0.09 ($/km)	0.10 ($/km)
Category B (Euro 3 and Euro 4)	0.11 ($/km)	0.12 ($/km)
Category C (Euro 1, Euro 2, and vehicles not in any emission category)	0.13 ($/km)	0.14 ($/km)

Source: Federal Ministry of Transport, Building and Urban Affairs, 2007

<u>2.1.2.3. Switzerland</u>

Switzerland mandated vehicles over 3.5 tons to pay a toll by applying a LSVA system which calculated fees based on three criteria: the distance a truck traveled, truck's maximum permitted weight, and the amount of truck emissions (Rapp and Balmer 2003). In 2001, Switzerland implemented a heavy vehicle fee (HVF) system to charge truck tolls based on the distance they traveled on the motorways. The system uses OBU with GPS technology and impulses transformed from an onboard unit in each truck to record distance traveled (Thomas 2003). Toll revenues were estimated to be up to one billion Euros in 2005 collected from 60,000 Swiss trucks and other foreign trucks passing through Switzerland with the OBU.

<u>2.1.2.4. United Kingdom</u>

Britain is planning to install a Lorry Road User Charging (LRUC) system to charge tolls on heavy trucks using UK roads in 2008. The LRUC uses satellite tracking and communication technology to calculate truck traveling distance. Toll rates vary by truck weight, number of axles, emission standard, class of road (motorways and other road types), and time of day (peak and off-peak periods) (McKinnon and McClelland 2004).

2.2. Issues and Opportunities Regarding TOT Lanes

Although the literature reviewed in the previous section is limited, it does point to some challenges that could arise from the implementation of TOT lanes including: (1)

political challenges, (2) financial challenges, (3) engineering challenges, (4) safety challenges, and (5) environmental challenges.

2.2.1. Political Challenges

Political challenges are related primarily to the concerns of the trucking industry and the public as described below.

2.2.1.1. The Trucking Industry

Although mandatory use of TOT lanes generates higher toll revenues and more easily controls truck traffic flow, this policy is usually opposed by the trucking industry. Principal opposition to TOT lanes is based on: (1) toll costs are perceived to be an excessive tax burden for truckers because they already pay federal fuel taxes of 24.4 cents per gallon of diesel (ATA 2007), (2) if toll rates are higher than the economic benefits of traveling on TOT lanes relating to travel time savings and trip reliability, truckers will shift to free alternative routes to avoid toll roads (David et al. 2005), and (3) if longer combination vehicles (LCVs) such as double or triple trailers are restricted from using TOT lanes, trucking productivity will decrease and operational costs will increase (Adrian 2004).

To put this in a positive way, trucks will likely use TOT lanes if the following conditions are implemented: (1) the use of TOT lanes is optional, not mandatory (ATA 2007), (2) tolls are not excessive, (3) trucks gain tax rebates or exemption from federal and state fuel taxes for every mile traveled on TOT lanes to reduce the tax burden (Robert 2004, Peter et al. 2002), and (4) LCVs are permitted to travel on interstate highways because LCVs can haul more efficiently and reduce shipping costs (Peter et al. 2002).

The trucking industry also prefers the deregulation of truck size and weight limitations on TOT lanes, a change which could increase freight productivity and reduce delivery costs. However, oversized and overweight trucks exceeding 57 feet and above

80,000 pounds such as LCVs could negatively impact TOT lanes (FHWA 2004). For example, the operating characteristics (sway, slow acceleration on upgrades, rollover in stability, and long stopping distances) and the large size/weight of triple-trailer trucks could cause serious and even fatal crashes, accelerate deterioration of pavement and bridges, and create difficulties in clearing incidents without disrupting traffic or blocking TOT lanes (Irvine 2000).

2.2.1.2. Public Reaction

The general public may support TOT lanes if TOT lanes can shift most truck traffic away from the general purpose lanes and thus reduce congestion and increase safety. Opposition to TOT lanes from the public may include the following reasons: (1) public opinion indicates that toll revenues paid by trucks to operate TOT lanes are preferred rather than levying new taxes from the public (David et al. 2005), particularly because TOT lanes mostly serve long-haul trucks that do not pay local taxes. Therefore, if bonds need to be repaid by public tax revenues, the public will likely oppose them; (2) motorists will oppose converting existing general purpose lanes into TOT lanes because that would reduce the number of existing general purpose lanes. Motorists may prefer building additional truck-only lanes to expand highway capacity; (3) motorists may oppose voluntary TOT lanes because some truckers could select free general purpose lanes to avoid tolls. This would cause more congestion and accidents on local roadways and reduce the benefits of investments in TOT lanes; and (4) the local community could oppose TOT lanes because they attract more truck traffic and thus possibly increase air pollution and noise along the corridor (STAR 2003).

2.2.2. Financial Challenges

Financial challenges primarily relate to the approaches used to finance the TOT lanes.

2.2.2.1. Financing Approaches

Traditional financing methods for toll road projects include the use of federal funds, state funds, and toll revenue bonds with varying combinations of each. The build-operate-transfer (BOT) approach has been used for toll road financing in Europe, Latin America, and Australia, but was not applied broadly in the U.S. until recently (Robert 2003).

Currently, many states in the U.S. have enacted laws for public-private partnerships (PPP) allowing private companies to finance and build new toll roads and then have the right to operate for several years. PPP uses a long-term authorization arrangement to reduce the cost paid by the state and increase the investment from a private company or consortium. For example, the California legislature authorized Caltrans to solicit proposals and make long-term franchise agreements with private companies to build new TOT lanes (SCAG 2004). The Virginia DOT planned a 60-year debt-plus-equity financing method to attract private investors, allowing private investors to collect revenue after the debt was paid off (VDOT 2006, STAR 2003).

The advantages of PPP include the following: (1) making the best use of private investment, (2) reducing the use of state and federal funds, and (3) speeding up the process of project construction. Even though a PPP can be beneficial, two potential problems need to be addressed: (1) private investors are usually interested in the most highly traveled corridors to obtain the maximum toll revenues, while other corridors with low truck volume have difficulty in implementing PPP, particularly for an entire state TOT network; and (2) if toll revenues fall far short of the expected level, private investors might lower the service level or sell it to reduce their loss (NYS DOT 2006).

2.2.2.2. Self-Financing Opportunity

FHWA's "Value Pricing Pilot Program" funded some states to implement congestion pricing strategies such as variable tolls based on traffic operational conditions to alleviate congestion on managed lanes (FHWA 2006). The trade-off between toll prices and truck usage is that higher tolls could increase toll revenues, but also reduce the utilization of TOT lanes. Truckers may select other free routes and cause toll revenues to fall short of project costs (Bob 2004). For example, in order to lower congestion and the number of accidents on the parallel free routes caused by large percentages of trucks trying to avoid a tolled turnpike, Ohio in 2005 reduced toll rates from 31 to 13 cents/mile (57%) for heavy trucks and from 15 to 11 cents/mile (26%) for commercial trucks. The result of the toll reduction attracted more than 10% of the trucks back to the turnpike (Ohio Turnpike 2006).

The Reason Foundation (Peter et al. 2002) proposed that toll truckways could be financed through toll revenues with tolls between 40 and 80 cents/mile based on 25% of current truck traffic using toll truckways. Georgia's study of HOT/TOT lanes on I-75 northwest estimated that mandatory TOT lanes scenarios would generate \$68.3 million ~ \$93.9 million net annual revenues in the projected year 2030; however, voluntary TOT lane scenarios would generate only \$5.4 million ~ \$35.9 million annually (SRTA 2006).

In sum, potential financial challenges include the following: (1) the selection of toll rates should be accepted by trucks and be sufficient to generate enough revenue; (2) voluntary TOT lanes may not attract enough truck traffic and generate sufficient toll revenues to cover operating and maintenance costs, particularly on rural highways with low truck travel demand; and (3) TOT lanes in urban areas may not raise enough revenue to cover construction costs if there are many short-length truck trips, which do not gain significant travel time savings by using TOT lanes.

2.2.3. Engineering Challenges

Engineering design issues associated with TOT lanes include the following major requirements: (1) number of lanes, (2) lane width, (3) location of TOT lanes, (4) barrier separation, (5) exclusive interchange and ramp, (6) pavement structure, and (7) electronic toll collection.

2.2.3.1. Number of Lanes

The Reason Foundation recommends that TOT lanes should have at least one lane in each direction and a passing lane every few miles (Robert et al. 2004). However, considering potential problems for passing maneuvers caused by travel speed differentials, emergency handling, incident clearance, and construction zone (Darrin 2005), TOT lanes should probably have at least two lanes in each direction. Two TOT lanes in each direction are important for congested highways with high truck traffic volumes. The major challenge for the number of TOT lanes is the acquisition of right of way along existing highways, particularly in urban areas. If there is not enough right of way to construct one or two TOT lanes in each direction, state DOTs need to purchase or create right of way on both sides.

2.2.3.2. Lane Width

The American Association of State Highway and Transportation Officials (AASHTO) recommends a minimum lane width of 12 ft for highways with high travel speed and high truck volumes. AASHTO also recommends the lane width of 16 ft for interchange ramps to handle LCVs' offtracking maneuvers (AASHTO Green Book 2004). Texas DOT recommends the lane width of 13 ft for dedicated truck roadways (Dan et al. 2003). In order to accommodate LCVs such as double and triple trailer rigs once LCVs are permitted on interstate highways in the future, some have recommended that the width of a TOT lane should be widened from an existing 12 ft to 14 ft (Robert et al. 2005). The major challenge is the additional construction costs of widening existing lane widths and reconfiguring existing ramp loops.

2.2.3.3. Location of TOT lanes

TOT lanes can be located on the inside (leftmost) lanes next to the median, outside (rightmost) lanes, or between them on existing interstates. For example, Virginia and Georgia proposed to build inside TOT lanes along I-81 (Virginia DOT 2004) and I-75 NW (Georgia DOT 2007). Texas proposed outside truck-only lanes on the multi-modal Trans-Texas Corridor-35 (TxDOT 2005). In addition, TOT lanes can be designed as elevated or tunnel structures (Robert et al. 2004), for example, SCAG's elevated TOT lanes (CALTRANS 2006).

The benefits of building TOT lanes in the inside lanes include the following: (1) the existing median can be used to build TOT lanes which is simple and has no need for additional right of way, and (2) inside TOT lanes is an appropriate design for a high percentage of through truck trips that have origins and destinations outside the corridor. Thus, weaving conflicts between cars that are frequently on and off freeways and through trucks that travel along inside TOT lanes can be reduced. However, once there is a high percentage of local truck traffic with origins or destinations within the corridor, it would be appropriate to build inside TOT lanes with access to major freight activity centers or build outside TOT lanes. The access for inside TOT lanes would not be by crossing over the general purpose lanes to a right-hand exit. The challenges of inside TOT lanes include: (1) building TOT lanes on existing interstate medians may be infeasible due to the lack of sufficient space in medians to add two or more lanes in each direction in the corridor, and (2) the complex relocation of existing HOV lanes, which are already located on the inside lane.

The benefits of building TOT lanes in the outside lanes include: (1) no need to relocate existing HOV lanes and general purpose lanes, (2) incident impacts such as fewer lanes blocked and easier access and clearing are reduced (Jodi 2005), and (3) TOT lanes are easier to add in the future. The challenges of outside TOT lanes include: (1) the difficulty to obtain additional right of way on existing highways, and (2) limits to future expansion of general purpose lanes and HOV lanes.

2.2.3.4. Barrier Separation

Barrier separation between TOT lanes and adjacent general purpose lanes or HOV lanes provides a protected driving environment to reduce the possibility of truck-car crashes. Barrier separation can include concrete, painted stripe, buffer, and grass. The concrete barrier is the safest, but most expensive separation. The painted stripe separation could save construction costs, but reduces safety. Grass separation provides a better scenic view, but needs additional right of way, which is particularly difficult for urban areas. A major challenge of barrier separation is to determine the location of restricted intermediate access/egress points, which connect to truck access ramps (FHWA 2004). Without intermediate access/egress points, TOT lanes could not provide service for local trucks with origins or destinations within the segment; on the other hand, continuous intermediate access/egress points could disrupt traffic operations on TOT lanes and increase construction costs.

2.2.3.5. Exclusive Interchange and Ramp

In order to reduce the conflicts of merging and weaving maneuvers between truck and car access to freeways, dedicated entry and exit ramps for trucks can be provided to separate them from general purpose access ramps (Peter et al. 2002). For example, TOT direct access ramps flying over general purpose lanes could be provided if TOT lanes are designed on the inside of interstate highways. The challenges for the exclusive interchange and ramps include: (1) the acquisition of right of way to build exclusive interchange and ramp, (2) the selection of access/egress points based on the connection to major interchanges, arterials serving as major access roads for large freight generators, and staging areas providing parking and rest facilities, and (3) the special design to accommodate the minimum turning radius for LCV maneuvers on ramps.

2.2.3.6. Pavement Structure

FHWA requires the gross vehicle weight limit of 80,000 pounds on interstate highways (FHWA 2004). However, a larger number of heavy trucks with five or more axles and over 80,000 pounds would increase pavement damage (James 2001). Therefore, in order to reduce the highway maintenance cost of pavement deterioration, the pavement of TOT lanes should be designed for a stronger and longer life to handle heavier trucks (Peter et al. 2002).

2.2.3.7. Electronic Toll Collection

An electronic toll collection (ETC) system can be used to collect tolls electronically by equipping transponders or electronic tags inside trucks to communicate with stationary electronic readers. The benefits of the ETC system include: (1) reduction in the delay and mobile emissions caused by stopping trucks for paying tolls, (2) increase in the efficiency of traffic flow and revenue collection, and (3) reduction in the operation cost of manually collecting tolls. In addition, an ETC system using variable pricing features would be able to charge tolls based on the time of day, travel direction, and level of congestion to maintain free-flowing traffic conditions on TOT lanes (Georgia SRTA 2005, Meyer et al. 2006).

Currently, two electronic toll collection systems including E-ZPass and PrePass are broadly implemented in the U.S. Passenger vehicles and trucks can efficiently travel through toll plazas by using an E-ZPass system (E-ZPass 2007). Car drivers can use E-ZPass tags to travel through other states in the northeastern U.S., including Virginia, Maryland, Delaware, New Jersey, Pennsylvania, New York, Massachusetts, and Maine.

Trucks can bypass weigh stations installed with a PrePass system by using PrePass transponders (PrePass 2007).

In European countries such as Germany and Switzerland, a new ETC system with on board units (OBU) based on global positioning system (GPS) technology has been used to collect tolls based on the distance trucks traveled on autobahns/motorways (Toll colect 2007, Thomas 2003). However, the feasibility of a GPS toll collection system in the U.S. is limited by: (1) the satellite technology is still too expensive for every truck to purchase, and (2) if there were mandatory use of OBU for trucks driving on tolled interstate highways, then trucks might select other routes to avoid using the OBU.

2.2.4. Safety Challenges

The principal safety challenges of TOT lanes relate to speeds and incident management.

2.2.4.1. Speed Limits

Currently, 24 states in the United States have increased truck speed limits on rural interstate highways to 70 mph or an even higher speed of 75 mph (Insurance Institute for Highway Safety, 2007). For example, truck speed limits are 70 mph on rural interstate highways in Georgia and Florida. However, 41 states still restrict truck speeds to no more than 65 mph on urban interstate highways. TOT lanes should have a higher design speed than trucks traveling on general purpose lanes because of the uniform traffic mix and the need to offer trucks higher speed in exchange for a toll. Higher operating speeds can increase freight productivity; however, they can also cause higher crash rates because heavy trucks or even LCVs need longer distances to stop and more space to operate on freeway lanes. In addition, once TOT lanes are planned on congested urban interstate highways, a significant speed differential such as greater than 20 mph between trucks traveling on congestion-free TOT lanes and cars traveling on congested general purpose lanes may cause a safety issue, if there is not a barrier to separate truck and car flows. Therefore, an appropriate speed limit on TOT lanes needs to be determined to increase efficient operations and reduce the occurrence and severity of collisions.

2.2.4.2. Incident Management

Due to the size and weight of heavy trucks, limited access to TOT lanes, and barrier separation from general purpose lanes or HOV lanes, crashes and incidents involving trucks in TOT lanes could have a significant impact on traffic flow. Incident management can reduce delays and maintain reliable travel time on TOT lanes by quickly clearing accidents involving trucks, removing stalled trucks, and handling accidents involving hazardous materials (David 2004). However, it would be difficult to implement incident management for TOT lanes with only one lane in each direction. In such a case, once an incident occurs, the police, ambulance, fire engine, and tow truck response could be limited due to lane blockage.

2.2.5. Environmental Challenges

Environmental challenges of building TOT lanes may arise from (1) increased air pollution and noise from a larger number of heavy trucks traveling on the corridors, and (2) potential damage to cultural and natural environment resources along TOT lane corridors such as historic properties, archeological sites, preserved open space, wetlands, and wildlife habitat for animals and plants (WSTC 2006, STAR 2004).

2.3. Factors for Feasibility Analysis of TOT Lanes

Important factors that affect the feasibility of TOT lanes include: (1) revenue generation, (2) traffic operational efficiency, (3) utilization of TOT lanes, and (4) truck diversion.

2.3.1. Revenue Generation

TOT lanes should cover a large portion of operating, maintenance, and capital costs of the lanes themselves. The success of financing TOT lanes is dependent on having an adequate truck volume and on the toll pricing strategy. Consistent truck volumes using TOT lanes and variable pricing which varies tolls by level of congestion, time of day, or travel direction are key elements to generate sufficient toll revenues.

The Reason Foundation (Robert et al. 2004) proposed revenue criteria to examine the financial feasibility of a toll truckway corridor in a projected year 2020, which included (1) daily truck volumes greater than 10,000, (2) high percentage of all miles in the corridor with daily truck volumes greater than 10,000, (3) high volume-to-capacity (V/C) ratios, (4) connectivity to existing LCV routes, and (5) support from trucking industries.

Georgia examined a revenue generation factor to evaluate the feasibility of regional TOT lane systems and recommended an alternative with the maximum revenue generation (Georgia SRTA 2005, Meyer et al. 2006).

2.3.2. Traffic Operational Efficiency

Feasible TOT lanes should maintain a good level of service, reliable travel speed, less delay, significant travel time savings, and safety. Performance measures regarding operational efficiency can be used to evaluate the feasibility of TOT lanes.

Georgia used the following performance measures to evaluate the Atlanta regional network of TOT lanes: (1) travel time savings by using TOT lanes as compared to general purpose lanes, (2) average travel speed on TOT lanes and general purpose lanes, (3) level of service (LOS) measured by V/C ratio on TOT lanes and general purpose lanes, (4) vehicle-miles traveled for passenger vehicles and trucks, and (5) vehicle-hours traveled (VHT) for passenger vehicles and trucks (Georgia SRTA 2005, Meyer et al. 2006). In addition, Georgia used the following performance measures to evaluate candidate truck-only lanes on the statewide interstate systems: (1) LOS measured by V/C ratio on TOT lanes and general purpose lanes, (2) truck volume on TOT lanes and general purpose lanes, (3) reduction in fatal truck crashes on general purpose lanes, (4) increase in trip reliability measured by the buffer time index, which is defined as congested travel time divided by free flow time on TOT lanes, and (5) percentage of freight by tons shift from rail to TOT lanes (GDOT 2007).

California used the following performance measures to evaluate the feasibility of a truckway on I-710 corridor: (1) volume-to-capacity (V/C) ratio on general purpose lanes and truck-only lanes, (2) average travel speed on general purpose lanes, (3) the percentage of truck volume on truck-only lanes attracted from general purpose lanes, and (4) the change in truck volume on general purpose lanes (LA County MTA 2005). Additionally, the following performance measures were used to evaluate I-710: (1) the increase in vehicle-miles traveled (VMT), (2) the reduction in vehicle hours traveled (VHT), (3) the reduction in person hours traveled (PHT), (4) accident reductions, and (5) travel time reliability measured as reduction in delays caused by accidents.

2.3.3. TOT Lane Utilization

Feasible TOT lanes should have high utilization rates to justify the investment. Mandatory TOT lanes would have 100% utilization; however, voluntary TOT lanes may not achieve reasonable utilization rates because some trucks would select free general purpose lanes or other routes (Georgia SRTA 2005, Meyer et al. 2006). Potential strategies to increase utilization rates of TOT lanes include: (1) using acceptable optimum toll rates for trucks, and (2) assuring significant benefits of travel time savings when using TOT lanes.

2.3.4. Truck Diversion

Feasible TOT lanes should attract a high percent of trucks from general purpose lanes or local roads, instead of causing truck diversion to free parallel routes (Reebie 2004, WSTC 2006). Truck traffic diversion from interstates to local roads could increase local congestion and crashes. Potential strategies to prevent high truck diversion rates include: (1) acceptable optimum toll rates for trucks, and (2) convenient access/egress points for truck trip origins or destinations between two TOT lane interchanges.

2.4. Measure of Trucker's Value of Time

A trucker's value of time varies by certain characteristics such as truck drivers, truck sizes, truck trips, loaded commodity, and operating areas. For example, a trucker's value of time is different between private drivers and for-hire drivers, medium trucks and heavy trucks, long-haul and short-haul, not fixed delivery schedule and penalty on late delivery, or non-congested rural highways and urban heavily congested area. Several methods have been used to measure a trucker's value of time including (1) net operating profit method, (2) cost saving method, (3) cost-of-time method, and (4) willingness-to-pay method (Adkins et al. 1967, Brian 2003, Kazuya 1999).

The net operating profit method calculates a commercial vehicle's value of time by estimating net operating profit derived from travel time savings. The cost saving method estimates commercial vehicle value of time based on the reduction of costs per unit of time. The cost-of-time method calculates commercial vehicle value of time by determining the cost of providing time savings. The willingness-to-pay method estimates commercial vehicle value of time based on the trade-off between time-saving benefits and money costs.

Two survey approaches including revealed preference (RP) and stated preference (SP) surveys are used to measure truckers' willingness-to-pay. RP surveys ask respondents' decision-making or choice behaviors based on actual choice situations. RP surveys are appropriate for choice data that can be observed but are unable to investigate respondents' preference for new facilities do not exist. SP surveys ask respondents' decision-making or choice behaviors based on hypothetical choice situations. SP surveys are broadly applied because they are not limited by available actual choice data and are able to deal with a wider variety of variables. However, the value of time from SP surveys could be lower than RP surveys because respondents may answer with lower values of time savings to avoid paying high toll costs in the future (Brownstone et al. 2003).

Since there is no existing TOT lanes in operation, SP surveys would be appropriate to estimate truckers' likelihood of using TOT lanes, described as follows.

2.4.1. Stated Preference Surveys

Two approaches including (1) logit models and (2) switching point analysis are primarily employed to estimate trucker's value of time from SP survey data.

2.4.1.1. Logit Models

Logit models use SP survey data to establish a utility function and derive the value of time from the ratio of the coefficients of travel time and toll cost (Brian 2003, Kazuya 1999). For example, if the utility function is defined as $U = \beta_{\text{toll cost}} \cdot \text{Cost} + \beta_{\text{travel time}} \cdot \text{Time}$, the value of time is defined as $VOT = \beta_{\text{travel time}} / \beta_{\text{toll cost}}$. Variables of different truck trip characteristics such as truck size, ownership, and loaded commodity can be analyzed by incorporating them into the utility function and comparing their utility coefficients.

2.4.1.2. Switching Point Method

A lognormal distribution curve fitted with the switching points of respondents' choices changing from toll routes to free routes under different toll rates was developed to estimate trucker's value of time (Brian 2003, Kazuya 1999). Information from stated preference surveys is used in the switching point method to measure truckers' values of time based on the cut-off point beyond which truckers choose free alternative routes rather than paying a toll for a given amount of time savings. For example, a respondent is willing to pay \$5 to save 10 minutes by using toll lanes but unwilling to pay \$6 for the same time saving. Therefore, the value of time is estimated as \$30/hr [(\$5*60mim/hr)/(10min)] or less than \$36/hr [(\$6*60mim/hr)/(10min)]. The value of time is estimated as the mean of the fitted switching points on the lognormal distribution curve. The mean value is much higher than the median (50 percentile) value because the lognormal distribution curve is skewed to the right (with a longer tail on the right) caused by a small percentage of truckers with fairly high value of time. Using the median value of time may underestimate the true number of truckers that are willing to use the toll road.

Georgia conducted SP surveys on I-75 and I-575 to measure passenger car drivers' willingness-to-pay in using HOT lanes and truckers' willingness-to-pay in using TOT lanes (SRTA 2006). Passenger car drivers traveling I-75/I-575 were asked questions about the trade-off of tolls and travel time savings between HOT and general purpose lanes, assuming respondents are single occupancy vehicle (SOV), high occupancy vehicle (HOV) 2 occupants, HOV 3 occupants, and HOV 4+ occupants respectively. Truckers were asked to choose traveling on TOT or general purpose lanes by giving a range of toll rates and corresponding traveling time savings, as shown in Table 2-2. The trade-off questions from the stated preference surveys are: (1) if truckers choose general purpose lanes, they can use them for free; or (2) if truckers use truck-only toll lanes, how much toll will they pay to save a specific amount of travel time. The switching point analysis was applied to estimate the values of time of auto drivers and truckers from their willingness-to-pay distribution curves, respectively. Trucker's mean value of time is approximately \$31/hr. The median value of time is approximately \$19/hr because a small proportion of for-hire truckers are willing to pay over \$200 per hour saving.

Table 2-2: SP Survey Trade-off Choice for Toll Levels and Time Savings on I-75

Toll Levels	Travel Time Savings				
	5 min	10 min	15 min	20 min	30 min
$1					
$2					
$3					
$5					
$6					
$7					
$9					
$10					
$12					
$15					
$18					
$20					

Source: Georgia SRTA, 2006

2.5. Methodologies of Screening TOT Lane Candidates

To understand the methodologies used to screen TOT lanes, this research reviewed relevant studies regarding screening approaches for TOT lanes and the selection approaches for optimum toll rates.

2.5.1. Screening Approaches of TOT Lanes

California used the following criteria to select truck-only lanes: (1) truck volumes exceed 30 percent of the vehicle mix, (2) peak hour volumes exceed 1,800 vehicles per lane-hour, and (3) off-peak volumes exceed 1,200 vehicles per lane-hour (CALTRANS 2006).

Florida used a GIS screening tool to determine potential highway corridors for truck-only lanes based on the following criteria: (1) high truck volume, (2) low level of service, (3) high percent of trucks, (4) high truck-related crashes, and (5) proximity to airport/seaport/truck terminal/railroad. Weights of those factors were 75% for truck volume, 15% for level of service, 5% for percent of trucks, and 5% for truck-related crashes (Florida DOT 2002, Stephen et al. 2003).

Georgia evaluated three TOT lane scenarios in Atlanta regional interstate systems including major truck corridors, service to commercial deliveries, and regional TOT network. Those scenarios were determined based on corridors with (1) high truck volumes, and (2) large through truck trips (Georgia SRTA 2005, Meyer et al. 2006). In addition, Georgia used the following evaluation criteria to identify candidate truck-only lanes on statewide interstate systems: (1) daily truck volume in both directions greater than 30,000, (2) congestion measured by level of service equal to E or worse on general purpose lanes, (3) major truck activity centers, (4) freight bottlenecks, and (5) corridors already been considered for improvement (GDOT 2007).

The Reason Foundation proposed the following criteria to consider a toll truckway: (1) interstate highway with average daily traffic of 40,000 in each direction, and (2) heavy trucks accounting for at least 20 percent of all traffic (Poole et al. 2004).

Wilbur Smith Associates conducted a study by using three major criteria and two secondary "service sensitivity" considerations to evaluate potential corridors for truck-only lanes along I-10 in eight states including California (CA), Arizona (AZ), New Mexico (NM), Texas (TX), Louisiana (LA), Mississippi (MS), Alabama (AL), and Florida (FL) (Wilbur Smith Associates 2003). The major criteria include: (1) very high total daily truck volume, (2) volume/capacity (V/C) ratios greater than 1.0, and (3) very high total overall vehicle volumes. The service sensitivity includes: (1) large numbers of trucks delivering high time-sensitive freight, and (2) large numbers of trucks making deliveries within 100 miles of the observed point.

2.5.2. Selection of Optimum Toll Rates

Pricing strategies are used to maintain free-flow traffic condition and generate revenues on managed lanes. Variable or dynamic toll pricing that vary toll rates by time of day or by real-time congestion level could shift some truck traffic from peak periods to off-peak periods and maintain an acceptable level of service. Truckers have various preferences regarding the trade-offs between toll costs and travel time savings. Therefore, variable toll rates for different time periods or travel directions manage truck travel demand on TOT lanes better than do flat toll rates. For example, for-hire truckers or truckers with a fixed delivery schedule may have a higher willingness to pay a higher toll to avoid possible delays during peak periods. Private truckers with a flexible delivery schedule or less route constraints might be more willing to pay a lower toll by shifting to off-peak periods or selecting free alternative routes.

Georgia used the criteria of maximum revenues and average travel speed above 45 mph to select the optimum toll rates on I-75 HOT/TOT lanes (SRTA 2006). The optimum toll rates were varied by time of day and travel direction.

Texas proposed to incorporate truck traffic diversion rates into the selection of toll rates. Toll rates are determined based on variable tolls by time of day and diversion rates that can shift trucks from congested I-35 to the new tolled highway SH 130 (Texas DOT 2005).

Virginia developed a toll diversion model to forecast the impact of different toll rates on the number of cars and truck diverting from tolled highways to free local roads (Reebie 2004). The results showed that (1) a low toll less than \$0.12/mile would have a small diversion of VMT to local roads, and (2) a toll between \$0.12/mile and \$0.30/mile would sharply increase the diversion of VMT.

Washington State determined optimum toll rates based on the generation of maximum revenues and the decrease of potential truck diversion to alternative routes (WSTC 2006).

2.6. Summary

This chapter reviewed several studies and projects regarding the implementation of TOT lanes and identified important factors and methodologies utilized in the planning process of TOT lanes. There are no existing TOT lanes in operation in Europe and in the

United States. However, ongoing truck-only lane or truck-only toll lane projects, designed to improve traffic congestion, reduce truck-related crashes, and increase productivity of freight movement, are being planned in certain states in the United States such as California, Georgia, Missouri, Texas, Virginia, and Washington.

The important factors associated with the implementation of TOT lanes include: (1) mandatory or voluntary use of TOT lanes requires careful assessment and support from the trucking industry, (2) a strategy to finance the TOT lanes should include a public-private partnership that involves private investors and reduces the financial burden on state governments, and (3) the accommodation of oversized and overweight trucks traveling on TOT lanes requires specific engineering designs such as two lanes in each direction, exclusive ingress/egress interchange ramps, a wider lane width, and a stronger pavement structure.

To identify corridor candidates for TOT lane, previous methodologies have reflected the following limitations: (1) the various criteria of congestion level, truck volume, truck percentage, and truck-related crashes have been used in combination by different studies, but no previous study has included all these criteria plus truckers' willingness-to-pay; and (2) truckers' willingness-to-pay has not been incorporated into screening criteria to determine the extent/boundary of a TOT lane corridor that trucks are willing to use. An additional issue not adequately addressed in previous methodologies relates to the determination of optimum toll rates. Beyond using the maximum revenue generation and an acceptable level of service as criteria to determine optimum toll rates, the truck diversion rate to assess the impact of local traffic congestion and safety and the utilization of TOT lanes to justify the transportation investment should be considered.

CHAPTER 3

DATA

The purpose of data collection for this research is to identify candidate TOT lanes on existing interstate highways, to validate travel demand models by replicating actual traffic conditions, and to examine toll level settings in relation to truckers' willingness to use TOT lanes. Datasets from the Atlanta region covering 20 counties used to obtain (1) total vehicle volumes, (2) truck classification counts, (3) truck-related crashes, and (4) trucker's willingness-to-pay are described as follows.

3.1. Total Vehicle Volumes

The purpose of collecting total vehicle volumes is to identify high travel demand corridors and to validate the Atlanta Regional Commission (ARC) travel demand model. Regional traffic volume data was estimated from the 2005 ARC travel demand model. The total volume of the annual average daily traffic (AADT) on individual road segments in the Atlanta interstate system ranges from approximately 3,000 to 156,000 vehicles with a mean of 55,000 and a standard deviation of 30,000. A high travel demand corridor is defined as a segment of interstate highway on which traffic volumes exceed 85,000 vehicles per day (the 85th percentile), a figure that falls outside one standard deviation of the mean AADT. Interstate highways carry high traffic volumes including I-75 north between I-285 and I-575, I-285 north between I-75 and I-85, I-85 north between I-285 and SR 316, I-285 west between I-85 and I-675, and I-75/I-85 connector, as illustrated in Figure 3-1.

Traffic count data of total vehicle volumes from the 2005 GDOT state traffic and report statistics (STARS) database were used to validate total vehicle volumes in the 2005 ARC travel demand model (GDOT STARS 2005). AADT data were obtained for each model highway link coded with the same traffic count station number as the GDOT STARS database. For the region-wide TOT lanes study, AADT data were collected from the 145 traffic count stations on the interstate system in the metro Atlanta region. The comparison of existing total vehicle volumes between ARC model data and GDOT traffic counts shows that most corridors have a difference of less than 10%. The most significant difference is along I-85 north in Gwinnett county and I-985 in Hall county because of interchange reconstruction at exit 106 and exit 16, respectively, as illustrated in Figure 3-2 and Table 3-1.

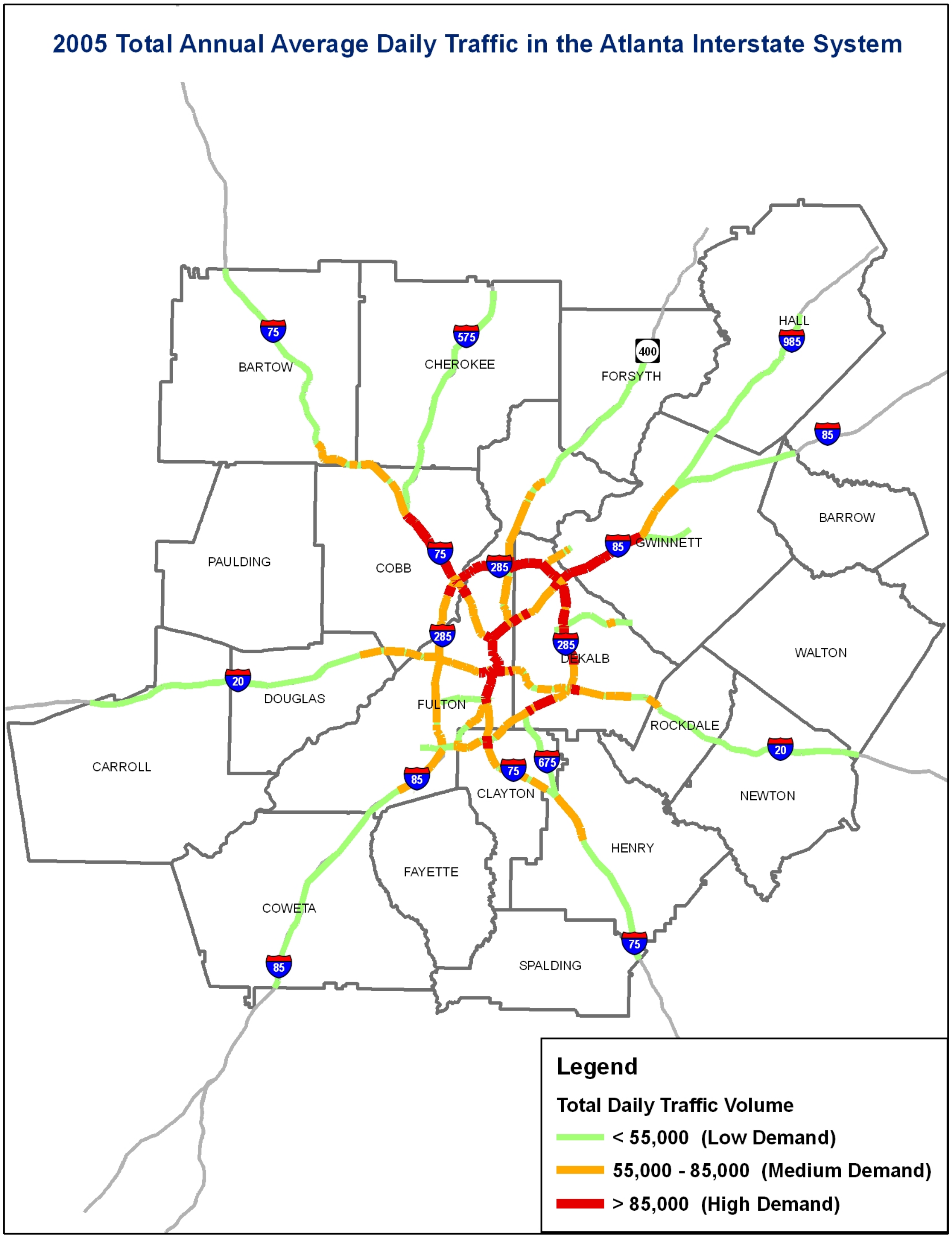


Figure 3-1: 2005 Total Daily Traffic Volume on Atlanta Regional Interstates

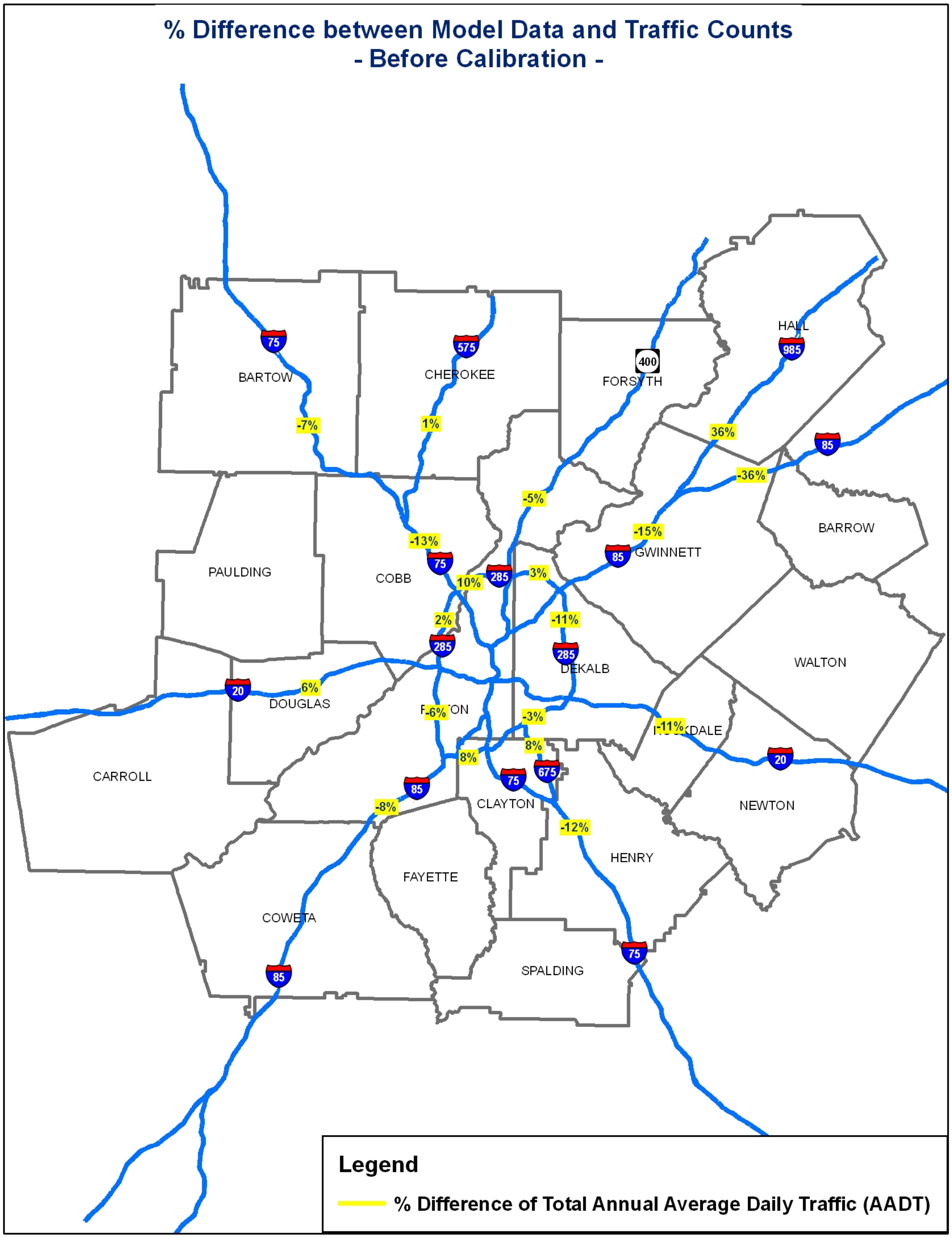


Figure 3-2: 2005 Total Daily Traffic Volume Comparison between ARC Model and GDOT Counts

Table 3-1: Percent Difference of Total Vehicle Volumes in the Atlanta Interstate System

Corridor	From ~ To	2005 GDOT Traffic Counts	2005 ARC Model Volumes	% Difference
GA 400	I-285N ~ SR 20	1,174,450	1,113,491	-5%
I-575	I-75N ~ SR 20	598,250	603,358	1%
I-75N I	I-285N ~ I-575	1,377,050	1,194,642	-13%
I-75N II	I-575 ~ SR 140	1,149,370	1,069,281	-7%
I-285N I	I-75N ~ GA 400	790,700	868,057	10%
I-285N II	GA 400 ~ I-85N	1,213,320	1,245,032	3%
I-85N I	I-285N ~ I-985	2,523,020	2,137,420	-15%
I-85N II	I-985 ~ SR 211	267,030	170,948	-36%
I-985	I-85N ~ SR 365	352,850	478,792	36%
I-285W I	I-75N ~ I-20W	786,540	804,253	2%
I-285W II	I-20W ~ I-85S	687,900	645,232	-6%
I-285S	I-75S ~ I-85S	371,650	400,023	8%
I-285E I	I-85N ~ I-20E	1,961,780	1,739,942	-11%
I-285E II	I-20E ~ I-75S	1,046,470	1,011,467	-3%
I-85S	I-285S ~ Jeff Davis Rd	766,100	706,218	-8%
I-75S	I-285S ~ SR 16	1,796,780	1,579,955	-12%
I-20W	I-285W ~ US 27	1,177,200	1,246,283	6%
I-20E	I-285E ~ US 278	1,474,970	1,307,577	-11%
I-675	I-285S ~ I-75S	302,130	327,673	8%

3.2. Truck Classification Counts

The purpose of collecting truck classification counts is to identify major truck corridors and to validate the ARC travel demand model. The ARC travel demand model defines truck classification based on the FHWA's vehicle classification, shown in Table 3-2 (FHWA 2003). Light trucks including passenger cars pulling one-axle or two-axle trailer, pickup trucks, vans, and small delivery vehicles are defined as being in a vehicle class from 2 to 3. Medium trucks including single-unit trucks with two to four axles are defined as being in a vehicle class from 5 to 7. Heavy trucks including tractors and trailers with more than three axles are defined as being in a vehicle class from 8 to 13.

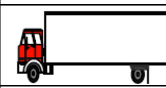
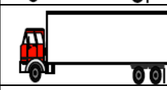
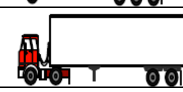
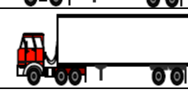
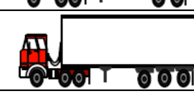
Derived from the 2005 ARC travel demand model, truck AADT on individual highway links including medium trucks and heavy trucks in the Atlanta interstate system ranges from approximately 8 to 20,000 trucks with a mean of 7,000 and a standard deviation of 4,000. Some very low truck volumes are located inside I-285 perimeter where heavy trucks are prohibited without a delivery permit. A high truck travel demand corridor is defined as a segment of interstate highway on which truck volumes are higher than 11,000 per day (the 85th percentile), a figure that falls outside one standard deviation of the mean truck AADT. High truck demand corridors include I-75 north between I-285 and I-575, I-285 perimeter, I-85 north between I-285 and I-985, two non-consecutive segments on I-75 south of I-285 (near I-675), and a short segment on I-20 west outside I-285, as illustrated in Figure 3-3.

The truck percentage of all traffic in the Atlanta interstate system ranges from approximately 0% to 45% with a mean of 14% and a standard deviation of 8%. A high truck percentage corridor is defined as a segment of interstate highway in which truck volumes account for more than 22% of all traffic (the 85th percentile), a figure that falls outside one standard deviation of the mean truck percentage. These high truck percent corridors are distributed along I-75 north within Bartow county, I-285 perimeter from I-20 west to I-675, I-85 north around I-985, and I-20 west within Carroll county, as illustrated in Figure 3-4.

Truck classification count data from the 2005 GDOT's automatic traffic recorder (ATR) and portable traffic count database were used to validate truck volumes in the 2005 ARC travel demand model (GDOT ATR 2005). Truck volumes were collected for each model highway link at the same location as GDOT's ATR database. For the region-wide TOT lanes study, data were collected from 11 truck class count stations on the interstate highways in the Atlanta region. The constraint of collecting truck class counts is that GDOT built a limited truck database at only specific locations.

The comparison between the ARC model data and the GDOT truck counts shows that all corridors have a difference of less than 22%. The significant differences are along the I-575 segment at I-75 north, the I-285 segment at I-675, the I-85 segment at the regional boundary, and the I-675 segment at I-285, as illustrated in Figure 3-5 and Table 3-3.

Table 3-2: FHWA Vehicle Classification

Vehicle Classes		FHWA Vehicle Classification	No. of Axles	Figures
1		Motorcycles	2	
2	Light Trucks	Passenger cars (or pulling 1-axle trailer, 2-axle trailer)	2 (or 3, 4)	
3		Other 2-axle, 4-tire single unit vehicles such as vans and pickup trucks (or pulling 1-axle trailer or 2-axle trailer)	2 (or 3, 4)	
4		Buses	2 or 3	
5	Medium Trucks	2-axle, 6-tire, single-unit trucks	2	
6		3-axle single-unit trucks	3	
7		4 or more axle single-unit trucks	4	
8	Heavy Trucks	4 or fewer axle single-trailer trucks	3 or 4	
9		5-axle single-trailer trucks	5	
10		6 or more axle single-trailer trucks	6 or 7	
11		5 or fewer axle multi-trailer trucks	5	
12		6-axle multi-trailer trucks	6	
13		7 or more axle multi-trailer trucks	7 or more	

Source: FHWA 2003, NYSDOT 2006

Table 3-3: Percent Difference of Truck Volumes in the Atlanta Interstate System

Corridor	Traffic Count Station Number	2005 GDOT ATR Truck Counts	2005 ARC Model Truck Volumes	% Difference
GA 400	80	5,019	5,429	8%
I-575	774	4,208	5,119	21%
I-75N	276	21,288	20,228	-5%
I-285N	3376	24,219	24,212	0%
I-85N	175	13,347	10,752	-19%
I-285E	3341	24,265	29,225	20%
I-85S	156	8,379	8,020	-4%
I-20W	5496	25,752	26,910	5%
I-20W	125	16,921	15,564	-8%
I-20E	209	8,212	7,901	-4%
I-675	927	10,561	8,931	-15%

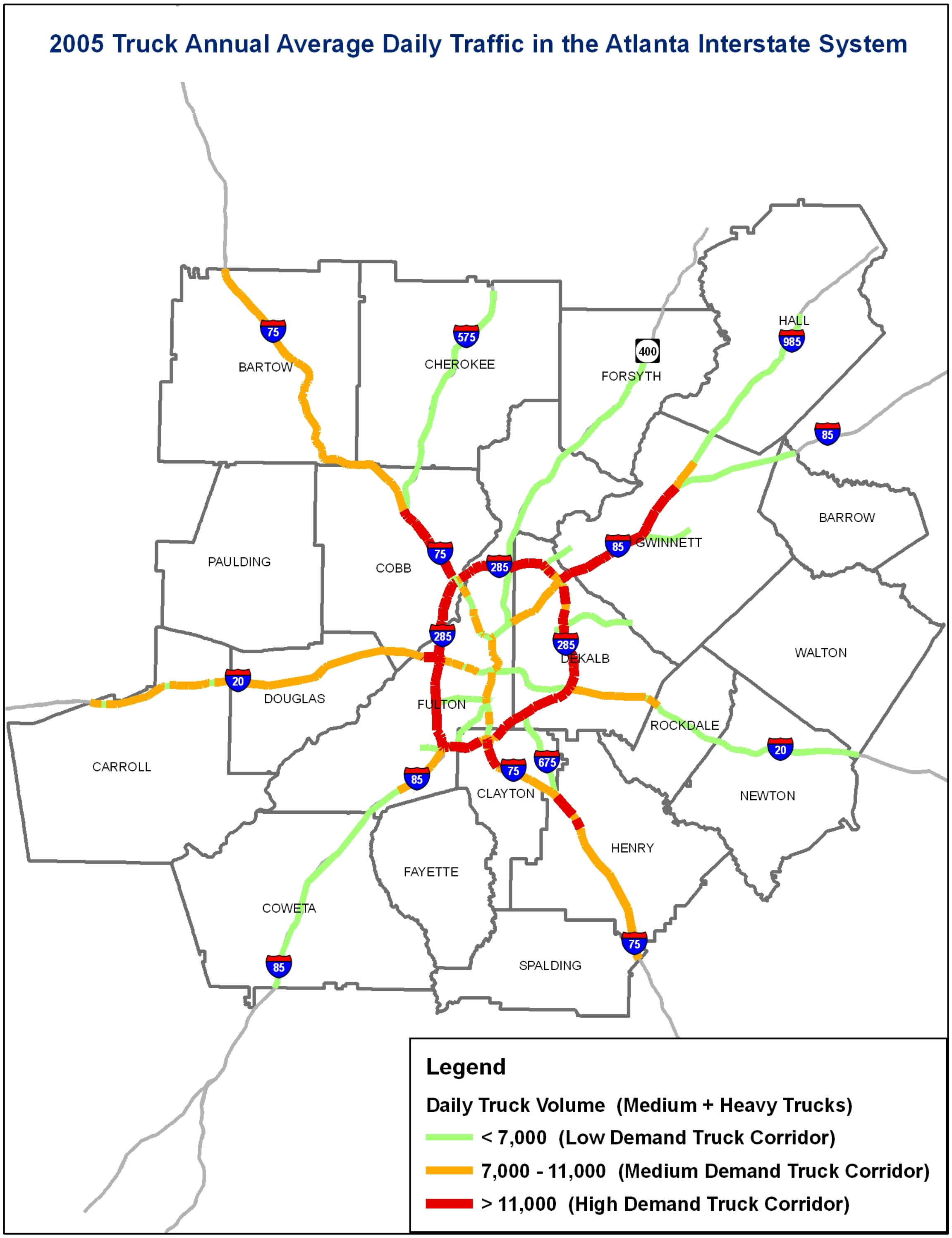


Figure 3-3: 2005 Daily Truck Volume on Atlanta Regional Interstates

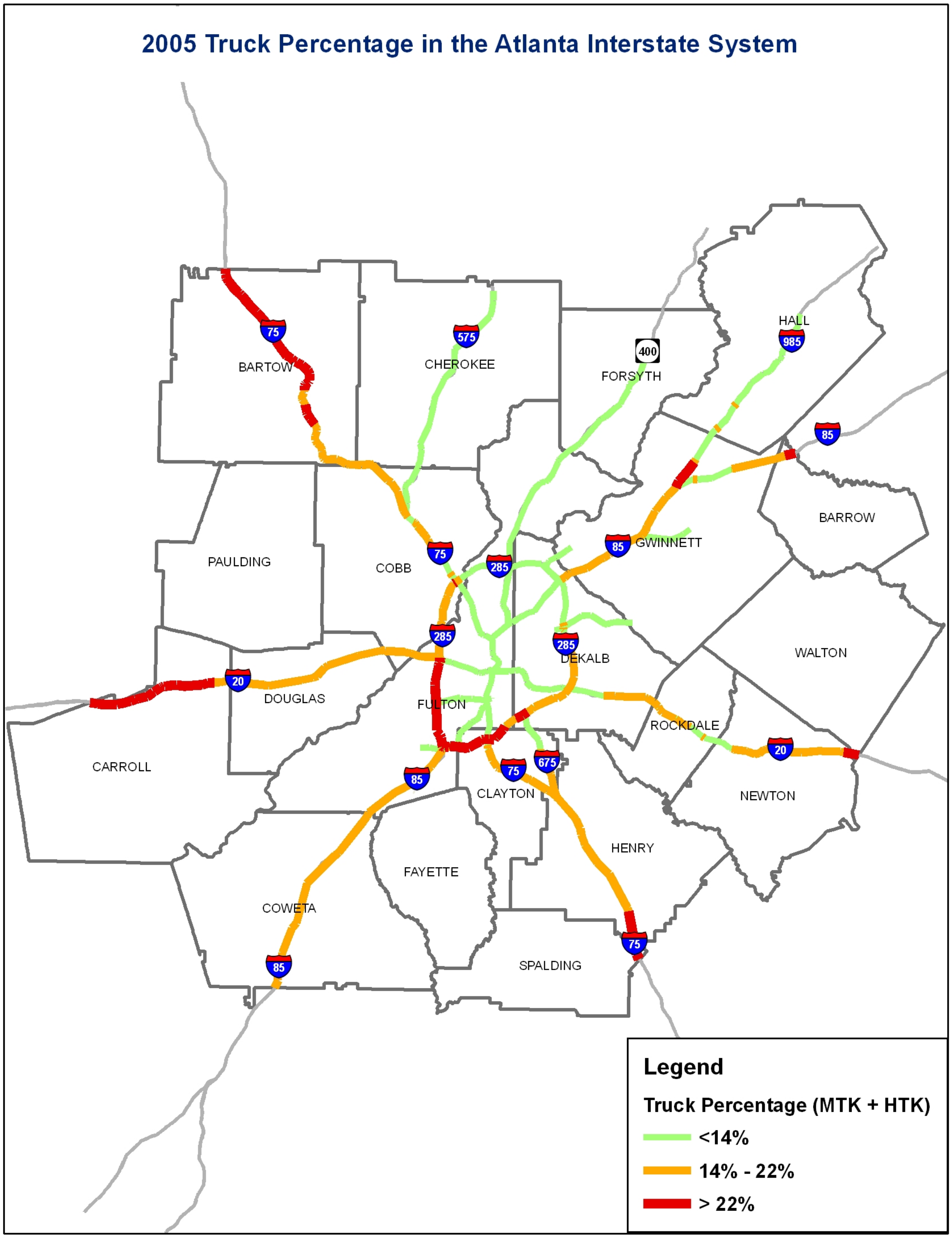


Figure 3-4: 2005 Truck Percentage on Atlanta Regional Interstates

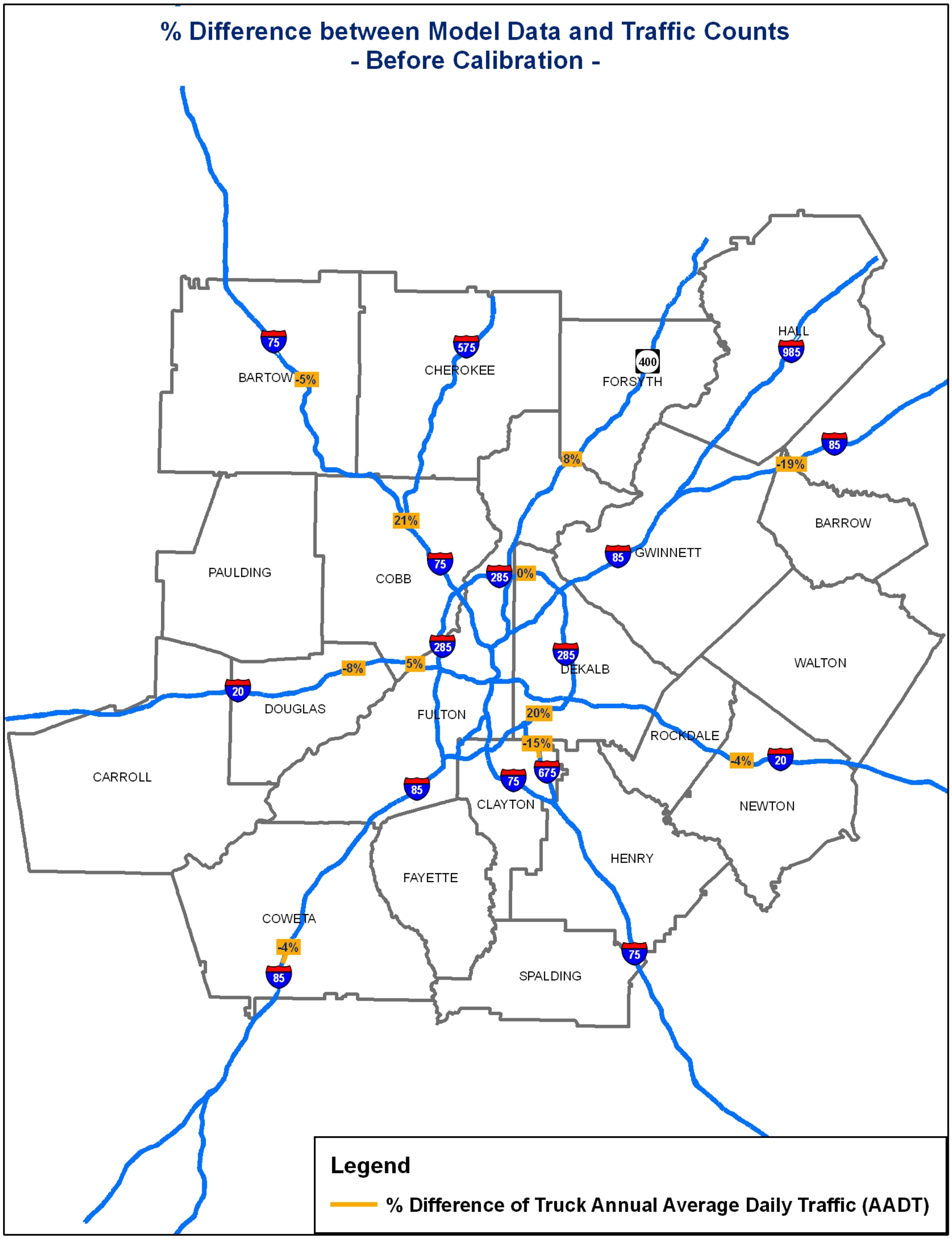


Figure 3-5: 2005 Daily Truck Volume Comparison between ARC Model and GDOT Counts

3.3. Truck-Related Crashes

The purpose of collecting truck-related crash data on interstate highways is to identify interstate segments with safety improvement potential. Data on crashes involving heavy trucks were collected from Georgia critical analysis reporting environment (CARE) data sources (Georgia CARE 2005). In order to prevent the regression-to-mean effect of natural fluctuation characteristics of crash occurrences, a six-year history of data from 2000 to 2005 was collected. The collected data included crash rates, crash severity (fatality, injury, and property damage only), and crash types (rear-end, sideswipe, angle, and others). The crash severity involving heavy trucks in the Atlanta regional interstate systems is 0.5% fatality, 20.7% injury, and 78.8% property damage only during the 6-year period. The crash types involving heavy trucks are 41.7% sideswipe, 32.7% rear-end, 14.7% angle, and 10.9% others. The high numbers of sideswipe and rear-end crashes are consistent with heavy trucks' operational deficiency of large blind spots and longer stopping distances.

A crash rate is defined as crashes per 100 million vehicle-miles traveled (VMT), calculated as follows:

$$\text{Annual crash rate} = \frac{100{,}000{,}000 \times (\text{Total number of crashes over 6 - year period})}{6 \text{ years} \times 365 \text{ days/year} \times \text{AADT} \times \text{Segment length in miles}}$$

The mean annual heavy truck-related crash rate including fatality, injury, and property damage only (PDO) on Atlanta regional interstates is 63 crashes per 100 million VMT from 2000 to 2005. The mean annual crash rates of fatality and injury involving heavy trucks are 0.38 and 13.7 crashes per 100 million VMT, respectively. Compared to the 2005 national fatality rate of 1.2 per 100 million VMT on urban interstate highways, Atlanta regional interstate highways have a lower truck-related fatality rate (FMCSA 2007). This research identifies the top 50 and top 100 truck-related crash locations in the Atlanta interstate system as an interstate segment experiencing a total crash rate of fatality, injury, and PDO of more than 206 and 131 crashes per 100 million VMT, respectively.

Most of the top 50 truck-related crash locations are on the I-285 perimeter north I-20, the I-85 north between I-985 and regional boundary, the I-75 south between I-285 south and I-675, and a short segment on I-20 west outside I-285, as shown in Figure 3-6. Furthermore, most of the top 50 fatality truck-related crash locations are on the I-75 north between I-575 and regional boundary, the I-285 east between I-85 north and I-20 east, and the I-85 south between SR 29 and regional boundary, as shown in Figure 3-7.

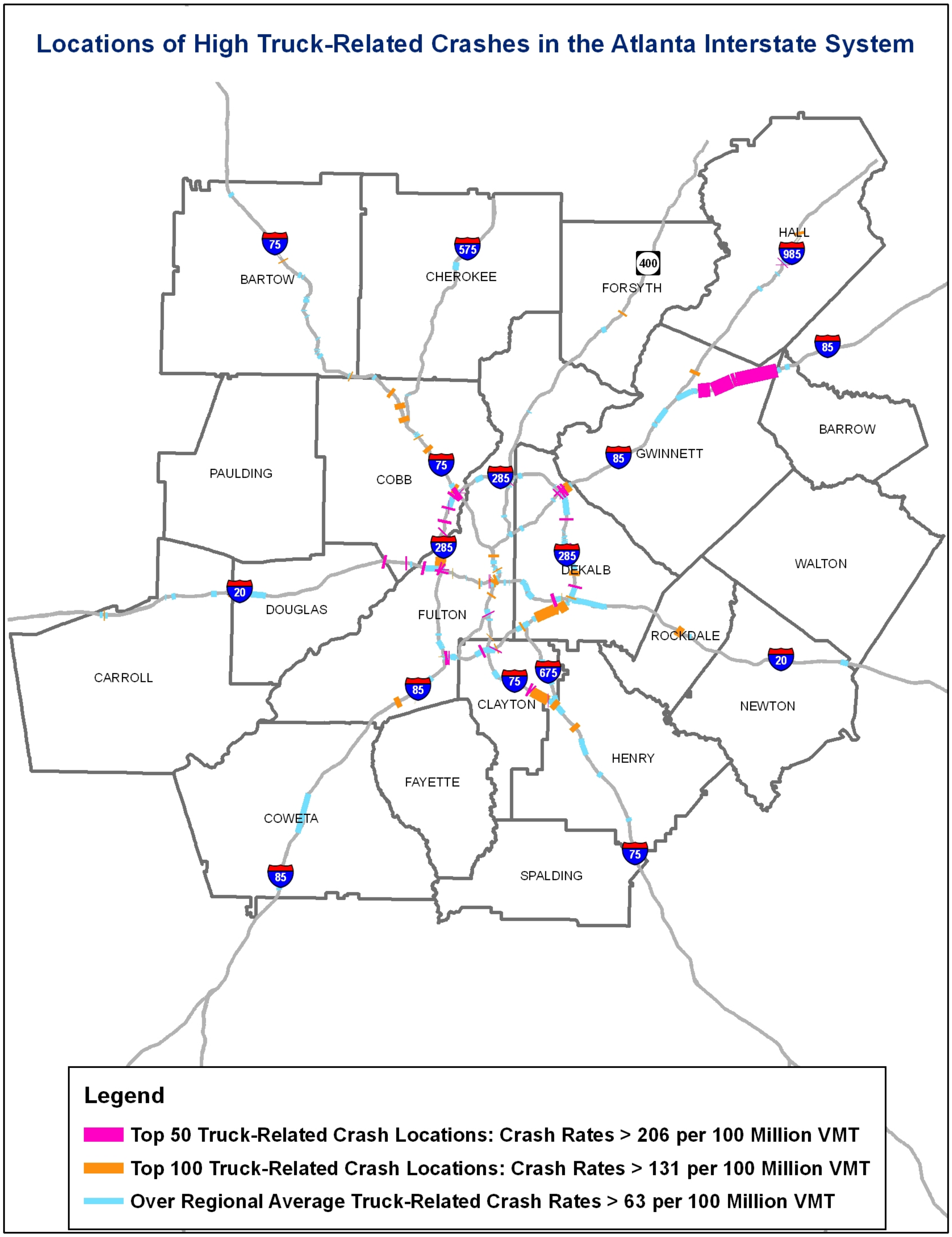


Figure 3-6: Locations of High Truck-Related Crashes on Atlanta Regional Interstates (2000 ~ 2005)

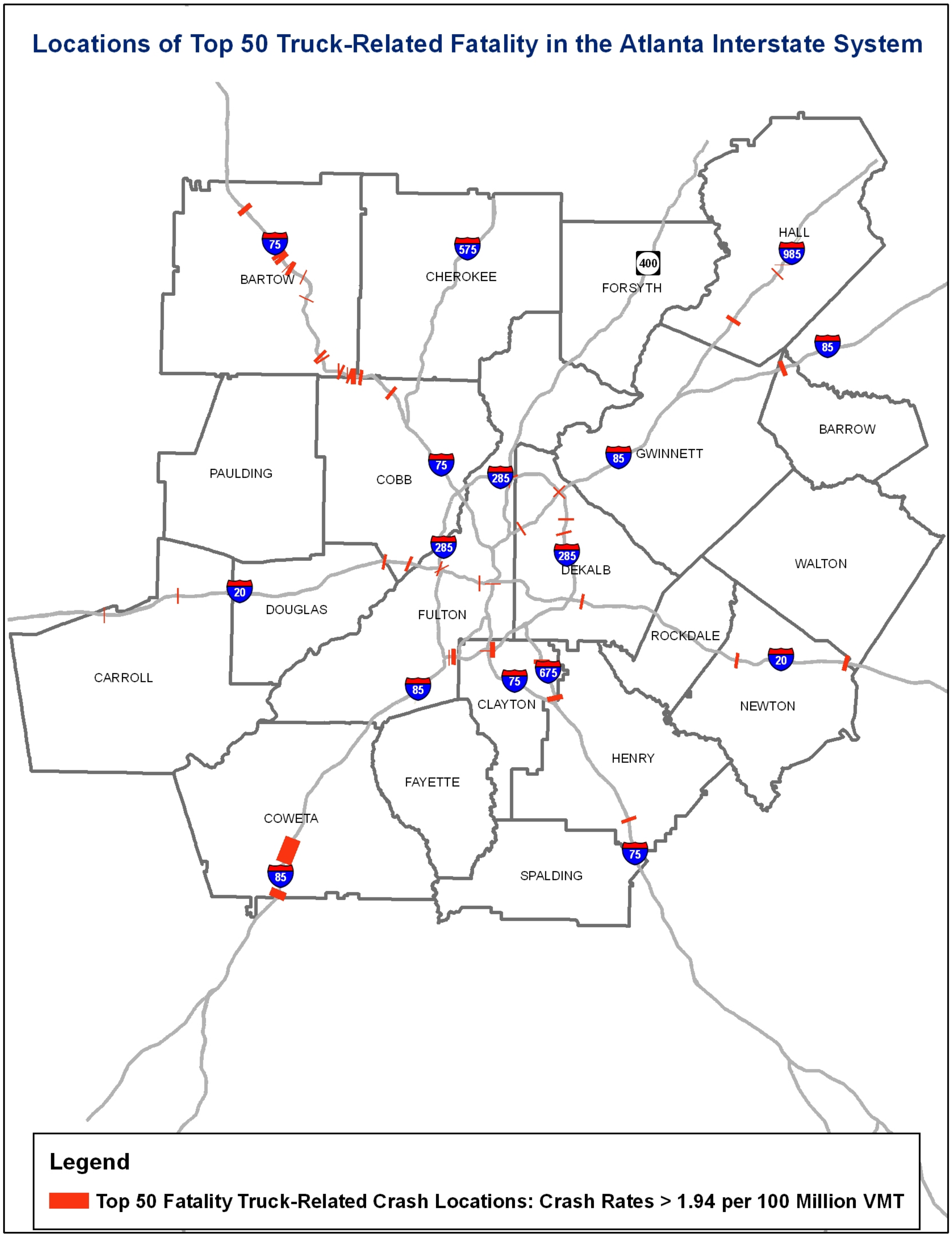


Figure 3-7: Locations of Top 50 Fatality Truck-Related Crash Locations on Atlanta Regional Interstates (2000 ~ 2005)

3.3.1. Relationship of Truck Volumes and Crashes

In general, the increase in truck traffic has a significant impact on increased truck-related crashes. According to the previous mapping results, most locations of high truck-related crashes (over the regional average crash rate) are consistent with locations of high truck volumes. The exception is I-85 north from I-985 to the regional boundary, which had low truck volumes, but experienced high truck-related crash rates because of interchange reconstruction in 2005.

This research examined the potential to improve efficiency and safety of highway freight movement based on the analysis of information regarding corridors experiencing high truck volumes and high truck-related crash rates. The results indicate that these existing safety deficient locations on relatively high truck volume corridors include (1) parts of I-75 north from I-285 north to I-575, (2) I-285 west from I-75 north to I-20 west, (3) I-285 east from I-675 to US 78, (4) parts of I-85 north from I-285 north to I-985, and (5) I-75 south from I-285 south to I-675, as illustrated in Figure 3-8.

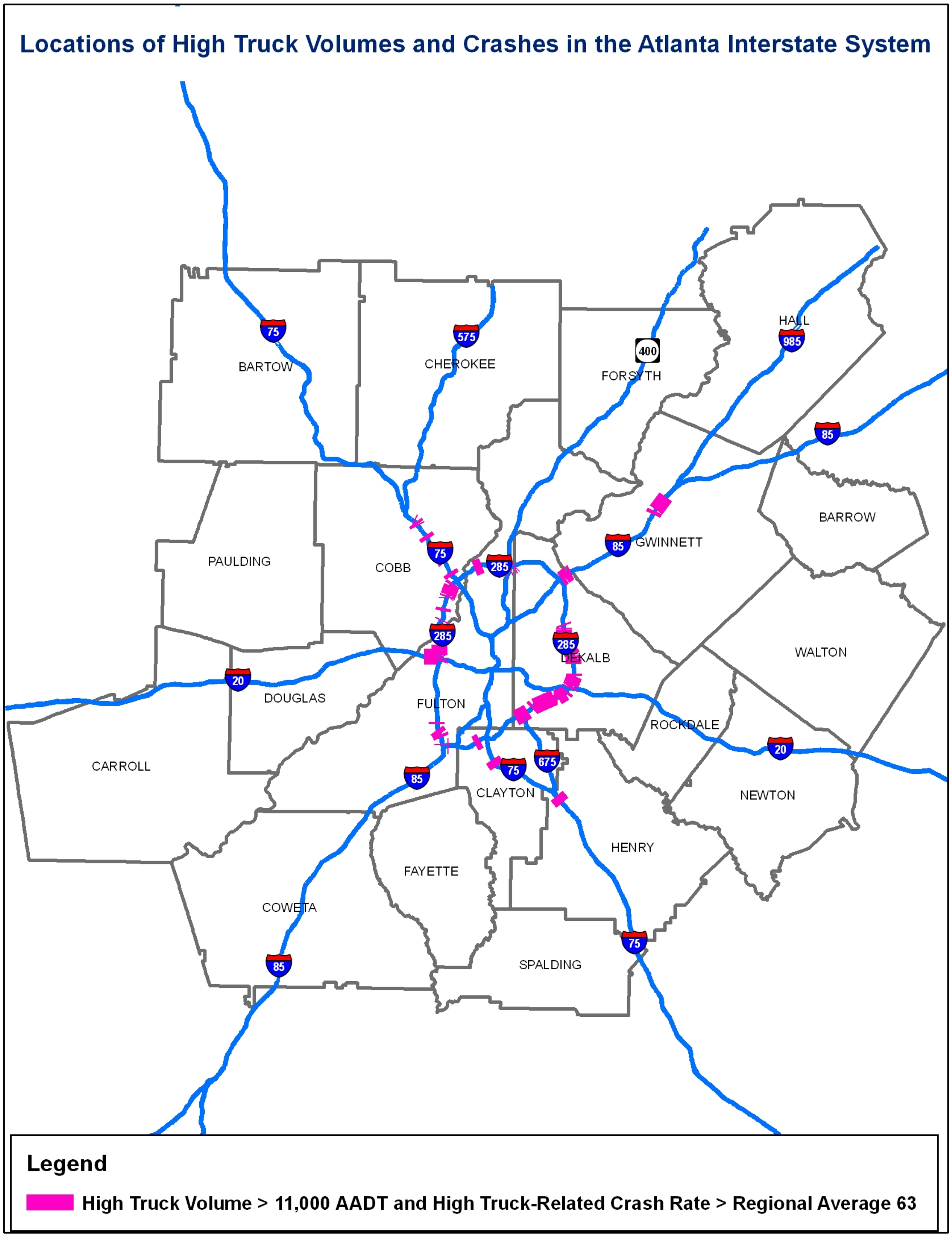


Figure 3-8: Locations of High Truck Volumes and High Truck-Related Crash Rates on Atlanta Regional Interstates

3.4. Truckers' Willingness-to-Pay

The purpose of collecting willingness-to-pay data is to examine the variation in truckers' willingness-to-pay to save travel time and to determine the pricing strategy for maximizing toll revenues on TOT lanes. Due to the lack of existing TOT lanes in operation, the trucker's willingness-to-pay is measured from information gathered in stated preference (SP) surveys. SP surveys estimate the trucker's likelihood of using TOT lanes based on the trade-off between toll costs and travel time savings. Trucker's value of time ($/hour) is calculated as a function of toll costs divided by travel time savings.

Truckers' willingness-to-pay data are compiled from the SP survey results of I-75 NW conducted by Georgia SRTA (SRTA 2006). Two target populations of carriers are included in truck SP surveys: trucking company shippers that own medium and heavy trucks; and individual truckers who drive heavy trucks as private drivers (38%) or for-hire (62%) by shipping companies. Shippers, the decision-makers for toll reimbursement, have a lower value of time than do individual truckers because shippers operate some medium-sized trucks and they want to reduce toll costs that must be reimbursed to truck drivers. In general, for-hire truckers have a higher value of time than private truckers because they have a less flexible delivery schedule causing lower sensitive to toll changes and they also can get reimbursed from their companies. The surveys show that approximately 70% for-hire truckers will get reimbursed for the toll costs they are willing to pay to exchange travel time savings. Private truckers decide for themselves the toll costs they are willing to pay for a reduction in travel time. The average value of time for shippers is approximately $22 per hour and $31 per hour for heavy truck drivers. Compared to trucker's value of time, the average value of time of single-occupancy vehicles (SOV) from SP surveys that measure a passenger car's willingness-to-pay to use high-occupancy toll (HOT) lanes on I-75 NW is approximately $5 per hour, which is lower than a trucker's value of time, as shown in Figure 3-9.

The willingness-to-pay distribution shows a broad coverage of trade-offs between toll costs and travel time savings from \$0.5 to more than \$200 per hour saving. Some truckers have higher willingness-to-pay because they have a fixed delivery schedule or a penalty on late delivery such as just in time delivery and because they can be reimbursed by their companies. The long tail of the distribution approaches lower or zero percent of willingness-to-pay gradually at very high values of per hour savings, which means only a very small percentage of cars and trucks have an extremely high value of time. For example, 90% of truckers would pay \$3 to exchange 60-minute travel time savings, while 85% of shippers and only 52% of passenger cars would pay the same fee to save 60 minutes. Although 50% truckers would pay \$15 to exchange 60-minute travel time savings, only 40% of shippers and 6% of passenger cars would pay the same fee to save 60 minutes. The percentages of truckers (26%), shippers (21%), and passenger cars (28%) that are willing to pay tolls to use the TOT and HOT lanes decline significantly as tolls rise to more than their average values of time of \$31/hr, \$22/hr, and \$5/hr. As tolls increase to more than \$240, only 9% of truckers and 5% of shippers are still willing to pay a toll. However, no passenger car is willing to pay more than \$51 for any amount of travel time savings.

In determining TOT lanes tolling structure, this research uses individual truckers' (including for-hire and private heavy truck drivers') willingness-to-pay rather than shippers' willingness-to-pay because truckers represent heavy trucks only instead of both mixed medium and heavy trucks. However, the constraints of employing truckers' willingness-to-pay data include the following: (1) because the limitation of acquiring SP surveys on all Atlanta regional interstates, this research uses truckers' willingness-to-pay data on I-75 NW to represent truckers' willingness-to-pay in all Georgia interstate highways and (2) because the SP survey information from shippers does not separate medium trucks from heavy trucks, medium truck drivers' values of time must be verified in the future.

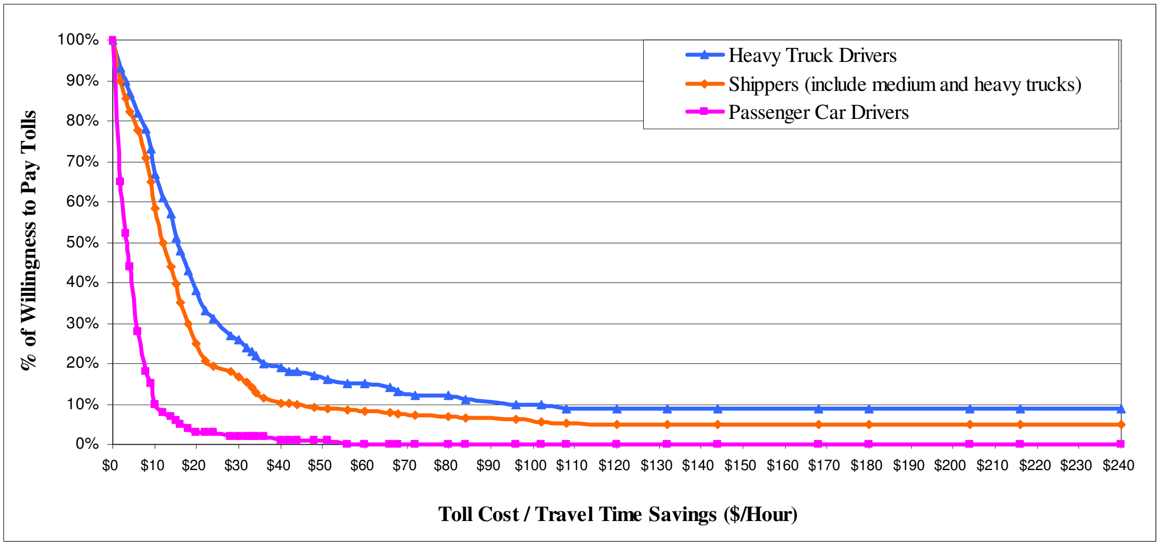


Figure 3-9: Distribution of Truck and Car Willingness-to-Pay Tolls on I-75

Source: SRTA "Value Pricing on the I-75 HOV/BRT Project", 2006

3.5. Summary

This chapter discussed data collection efforts and statistical methods related to the identification of TOT lane candidates. Four types of data are collected in this research: total vehicle volumes, truck classification counts, truck-related crashes, and truckers' willingness-to-pay. The total vehicle volume data, truck volume data, and truck-related crash data cover the 20-county metro Atlanta area; however, the limitation of truckers' willingness-to-pay data is obtained from stated preference surveys only on the I-75 corridor. Another constraint of this research is that truck volume data in the Atlanta interstate system obtained from GDOT's automatic traffic recorder and portable traffic count databases is limited.

This research examines region-wide total vehicle volumes and truck volumes, which are used to validate the travel demand model and to identify high travel demand corridors and major truck corridors. The 85th percentile of total vehicle volumes and truck volumes on Atlanta regional interstate highways is defined as a threshold value for a high travel demand corridor and a major truck corridor.

In addition, truck-related crashes including fatality, injury, and property damage only (PDO) collected from 2000 to 2005 on Atlanta regional interstates are used to identify potential improvements for highway safety. A location with a truck-related crash rate over the regional average of 63 crashes per 100 million VMT is defined as a truck high-crash location. Specifically, the top 50 truck high-crash locations over 206 crashes per 100 VMT would have higher priority for safety improvement. The results show that, in general, a corridor which experiences high truck volume also has high truck-related crash rates in the Atlanta interstate system.

Truckers' willingness-to-pay data shows heavy trucks have a lower average value of time of $31 per hour in Georgia than values of time in some states such as California ($73/hour) and Virginia ($60/hour). The relationship between the percentage of truckers willing to use TOT lanes and the trade-off between toll fees and travel time savings is applied to determine the toll structure.

CHAPTER 4

RESEARCH METHODOLOGY

This chapter describes the methodology that is used to identify feasible TOT corridors. The application of this methodology to the Atlanta regional freeway system is used to illustrate each of the steps in the methodology.

4.1. Methodology Overview

The research methodology is showed in the Figure 4-1. The fist step is to collect data including total vehicle counts, truck class counts, truck-related crashes, and truckers' willingness-to-pay. Existing traffic count data were used to validate the 2005 ARC travel demand model and identify major truck corridors. Truck-related crashes and truckers' willingness-to-pay were used to identify locations for safety improvement and potential corridors that trucks are willing to use, respectively.

Five screening criteria are developed to identify feasible TOT corridors and segment boundaries by employing the validated travel demand model. Four primary criteria include low levels of service, high truck volumes and percentages, and the monetary value of travel time savings gained from using TOT lanes more than the toll cost of truckers' willingness-to-pay. One secondary criterion uses truck-related crashes to identify hazardous locations and provide the priority ranking for highway safety improvement projects. Furthermore, various levels of truckers' willingness-to-pay are tested to reflect the application to different truck trip characteristics.

Engineering design of TOT lane placements whether at the inside or outside lanes is assessed by the scale of through truck trips, the acquisition of right of way, and the need to relocate existing high occupancy vehicle lanes.

The optimum toll rates are determined based on a TOT corridor that can maximize revenue generation, maintain an acceptable level of service, produce a TOT lane utilization rate of greater than 50%, and create a truck diversion rate from local roads to TOT lanes greater than 0%.

Feasible TOT lane candidates are identified based on the performance assessment of different scenarios regarding adding general purpose lanes or building new TOT lanes, and implementing mandatory TOT lanes or using voluntary TOT lanes. In addition, different levels of truckers' value of time are examined to analyze their performance measures for the purpose of different geographic application.

Finally, research conclusions and a TOT lane planning guidance are proposed as a contribution to the transportation community.

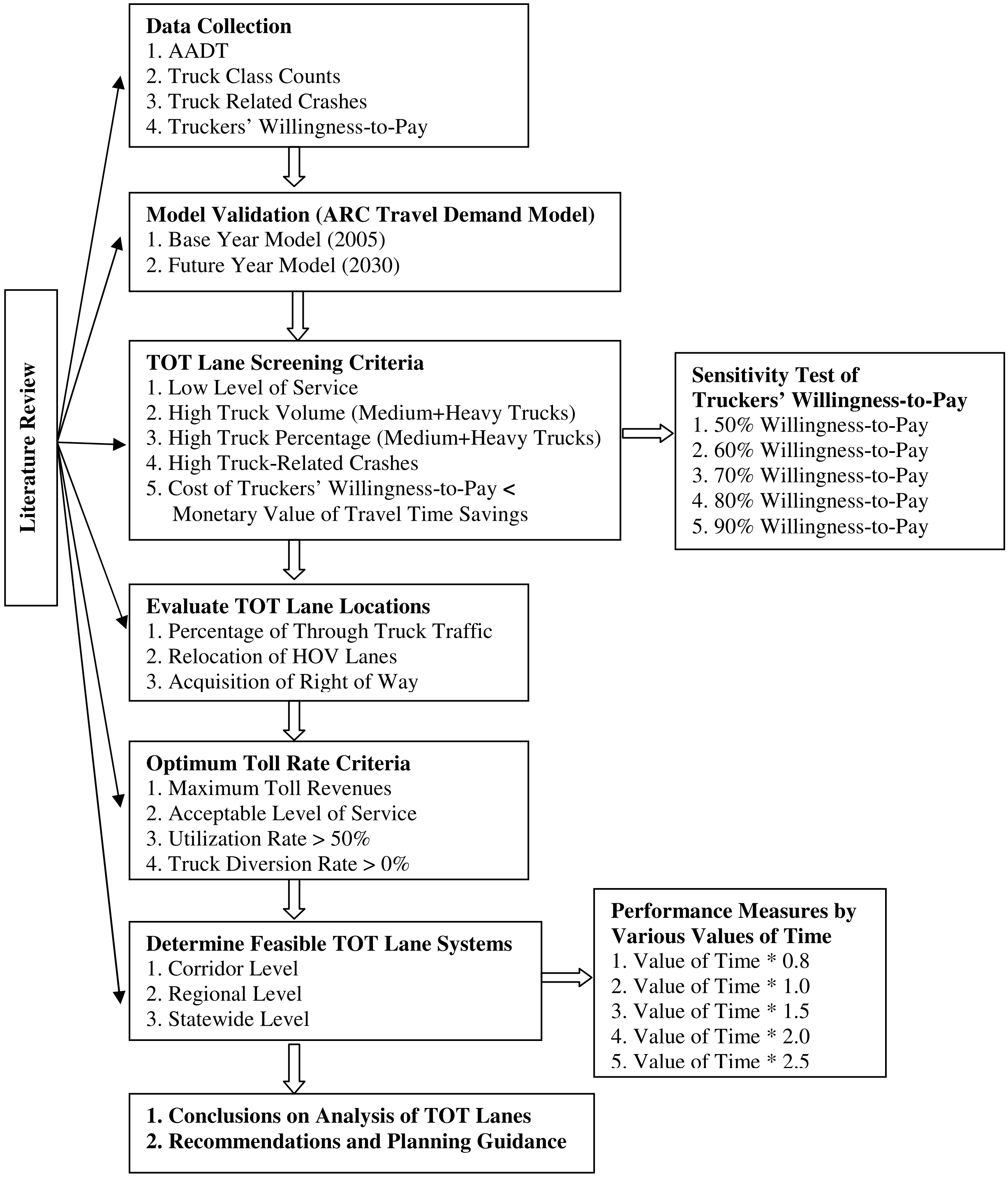


Figure 4-1: Flowchart of the Research Methodology

4.1.1. Research Methodology Limitations

The limitations of the research methodology are as follows:

(1) Truckers' willingness-to-pay among various corridors. Given that stated preference surveys were conducted only in the I-75 NW corridor, this research uses the I-75 NW data as being representative of all corridors.

(2) Differentiating truckers' willingness-to-pay between heavy trucks and medium trucks. No willingness-to-pay data have been collected for medium trucks.

(3) Modeling truck trip reliability on TOT lanes. A buffer time is defined as the 95th percentile travel time minus the average travel time. Less buffer time means higher trip reliability. Since there are no existing TOT lanes from which to obtain continuous truck travel time data and to develop the buffer time index, the research methodology does not include a forecasted reliability function to estimate TOT lane buffer time.

(4) Modeling truck trips assignment in the statewide travel demand model. The traffic analysis zone (TAZ) structure in the Georgia statewide travel demand model is developed at the county level, which means each county represents one TAZ. However, if trip origins and destinations are in the same county, these trips cannot be assigned to the freeway network, an omission which limits trip distribution results. Therefore, this research will use the statewide model to identify initial truck lane needs by applying the proposed methodology. However, a metropolitan planning organization (MPO) model, the ARC travel demand model, in which TAZs are much smaller than a county, is used to develop detailed evaluation criteria for TOT lanes.

4.1.2. Assumptions

The following two major assumptions pertain to the application of the methodology:

(1) The distribution of truckers' willingness-to-pay for the I-75 NW corridor, an urban interstate highway, is the same as other interstate highways in Georgia. This

assumption might overestimate truckers' likelihood of using TOT lanes, particularly on rural interstate highways where congestion is not a significant issue.

(2) The value of time of medium trucks is the same as heavy trucks. This assumption might overestimate toll revenue generation if medium truck drivers' value of time is significantly lower than that of heavy truck drivers'.

4.2. Validation of the Travel Demand Model

The purpose of model validation is to accurately replicate existing travel volumes and forecast future travel demand in the regional transportation system. The collection of existing traffic count data from the GDOT database was used to conduct the validation of the base year travel demand model.

In order to refine model data and reflect actual traffic conditions on study corridors, existing traffic count data are used to validate highway link volumes generated from the 2005 ARC travel demand model. Based on FHWA's recommended validation criteria (FHWA 1997), the percent difference target should be less than 10% for aggregated volumes of screenlines, identified as interstate corridors. Furthermore, the percent difference targets for individual link volumes on the screenlines, for example, within 25,000 to 50,000 should be less than 22%, as shown in Table 4-1. A percent difference is calculated as a model volume minus a traffic count, divided by the traffic count. In addition, two statistical measures - the square of the correlation coefficient (R-square) and the percent root mean square error (% RMSE) - must be examined. The R-square measured from the region-wide comparison between traffic counts and model volumes should be higher than 0.88 to represent traffic counts and model volumes accurately. The % RMSE measuring the deviation between traffic counts and model volumes should be less than 30% for all highway links with traffic counts along a corridor. The computation of % RMSE is as follows:

$$\%\ \text{RMSE} = \frac{100 \times \sqrt{\dfrac{\sum_j \left(Model_j - Count_j\right)^2}{\left(Number\_of\_Counts - 1\right)}}}{\left(\dfrac{\sum_j Count_j}{Number\_of\_Counts}\right)}$$

Based on the analysis of the data on the Atlanta regional interstate system, a desirable validation target of 10% difference or lower between model daily total vehicle volumes and GDOT traffic counts is applied to all selected corridors. Regarding truck volume calibration, since model truck volumes are selected only from individual highway links with truck classification counts, this research uses a target of 22% to validate model daily truck volumes, which are in a range of 5,119 to 29,225 AADT.

According to the analysis of validation results, the R-square of the scatter plot is equal to 0.95, which represents a good fit of model volume and GDOT traffic counts, as illustrated in Figure 4-2. Table 4-2 shows the percent difference between the model volumes and traffic counts. A maximum desirable percent difference curve is utilized to examine the tolerable deviation between model link volumes and traffic counts, as illustrated in Figure 4-3 (NCHRP 255, 1982). The maximum desirable percent difference for individual links is calculated as follows:

Maximum desirable percent difference $_{\textbf{link i}}$ = $38.262 \times \left(\dfrac{Count_i}{10{,}000}\right)^{-0.4361}$

The data points in Figure 4-3 illustrate that most links in the model network are assigned reasonable traffic volumes. The fact that some links lie outside the maximum desirable percent difference curves results from an inability to accurately replicate traffic volumes on I-85N and I-985 due to interchange reconstruction during the collection period.

The comparisons of total vehicle volume and truck classifications between 2005 ARC model outputs and existing GDOT traffic counts are illustrated in Figure 4-4. Overall, most corridors in the Atlanta region show an acceptable percent difference of less than 10% for total corridor volumes and less than 22% difference for individual link truck volumes. The goal of the calibration process is to reach an acceptable level of difference and to reflect the observed traffic counts as accurately as possible. For corridors that show more than ±10% difference in total corridor volumes or more than ±22% difference in individual link truck volumes, free-flow speed is changed to make links more attractive (increase traffic volume) or less attractive (decrease traffic volume). For example, if a corridor shows a +18% difference compared model volumes to observed traffic counts, then the free-flow speed of 65 mph may be adjusted to 55 mph to reduce model volumes till it reaches the acceptable 10% difference. Figure 4-5 illustrates the comparison of calibrated model volume data, which are within the acceptable biases of less than 10% for interstate corridors and less than 22% for individual links.

Table 4-1: Percent Difference Targets for Daily Volumes for Individual Links

AADT	Desirable Percent Difference
< 1,000	60%
1,000 ~ 2,500	47%
2,500 ~ 5,000	36%
5,000 ~ 10,000	29%
10,000 ~ 25,000	25%
25,000 ~ 50,000	22%
> 50,000	21%

Source: FHWA, Model Calibration and Reasonableness Checking Manual, 1997

Table 4-2: % Difference & % RMSE after Calibration in the Atlanta Interstate System

Corridor	From ~ To	2005 GDOT Traffic Counts	2005 ARC Model Calibrated Volumes	% Difference	% RMSE
GA 400	I-285N ~ SR 20	1,174,450	1,116,493	-5%	10%
I-575	I-75N ~ SR 20	598,250	588,066	-2%	8%
I-75N I	I-285N ~ I-575	1,377,050	1,242,099	-10%	13%
I-75N II	I-575 ~ SR 140	1,149,370	1,090,008	-5%	18%
I-285N I	I-75N ~ GA 400	790,700	877,670	10%	12%
I-285N II	GA 400 ~ I-85N	1,213,320	1,245,666	3%	5%
I-85N I	I-285N ~ I-985	2,523,020	2,278,280	-10%	12%
I-85N II	I-985 ~ SR 211	267,030	210,953	-21%	29%
I-985	I-85N ~ SR 365	352,850	478,792	17%	22%
I-285W I	I-75N ~ I-20W	786,540	812,032	3%	5%
I-285W II	I-20W ~ I-85S	687,900	645,467	-6%	7%
I-285S	I-75S ~ I-85S	371,650	401,318	8%	21%
I-285E I	I-85N ~ I-20E	1,961,780	1,784,270	-9%	12%
I-285E II	I-20E ~ I-75S	1,046,470	984,333	-6%	16%
I-85S	I-285S ~ Jeff DavisRd	766,100	707,362	-8%	10%
I-75S	I-285S ~ SR 16	1,796,780	1,661,432	-8%	11%
I-20W	I-285W ~ US 27	1,177,200	1,243,972	6%	9%
I-20E	I-285E ~ US 278	1,474,970	1,343,943	-9%	13%
I-675	I-285S ~ I-75S	302,130	314,233	4%	10%

Notes: 1. The validation targets of corridor total volumes are ±10% difference and ±30% RMSE.
2. The high % difference on I-85N II and I-985 are attributed to interchange reconstruction.

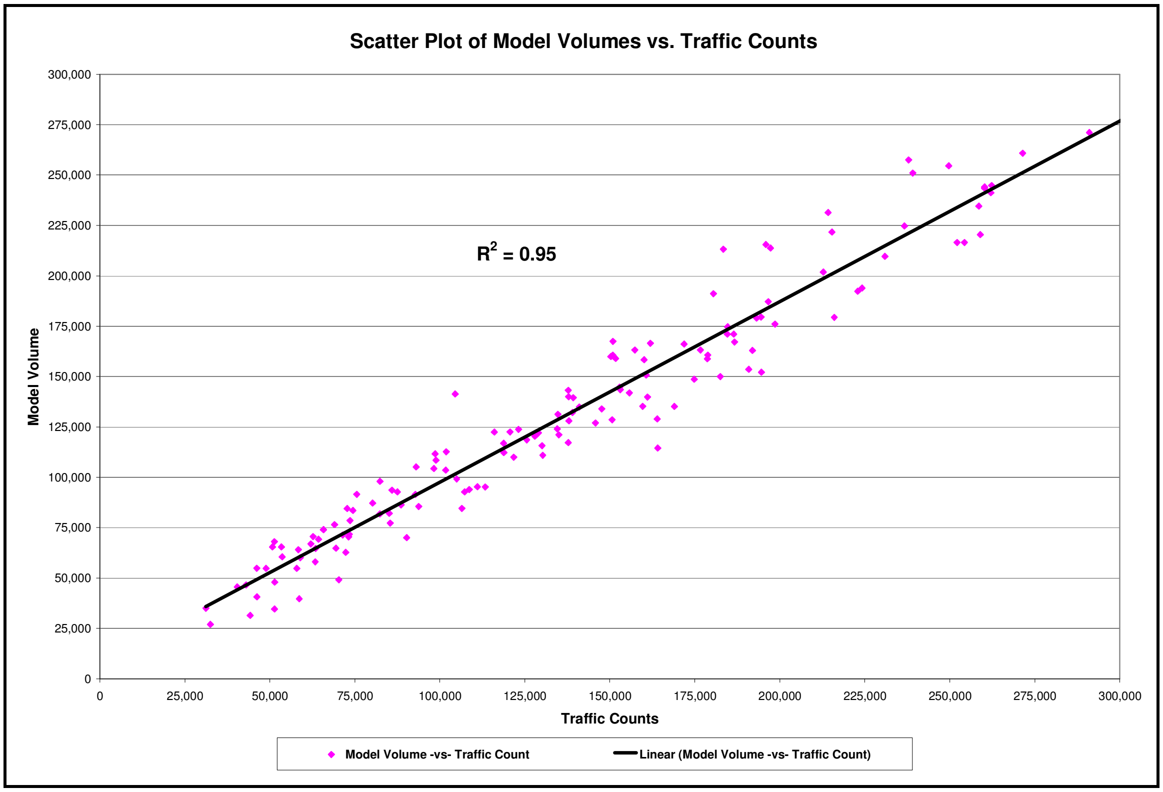


Figure 4-2: Scatter Plot of Model Volumes vs. Traffic Counts

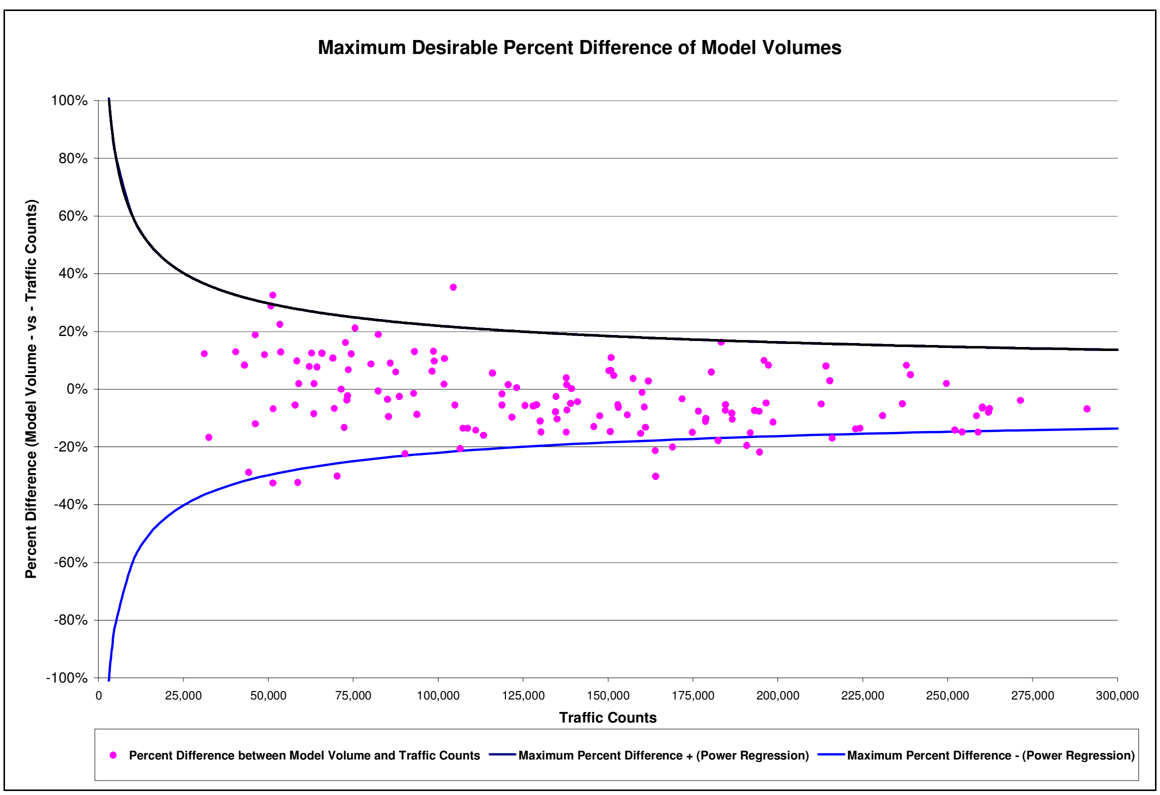


Figure 4-3: Maximum Desirable Percent Difference in Model Link Volumes

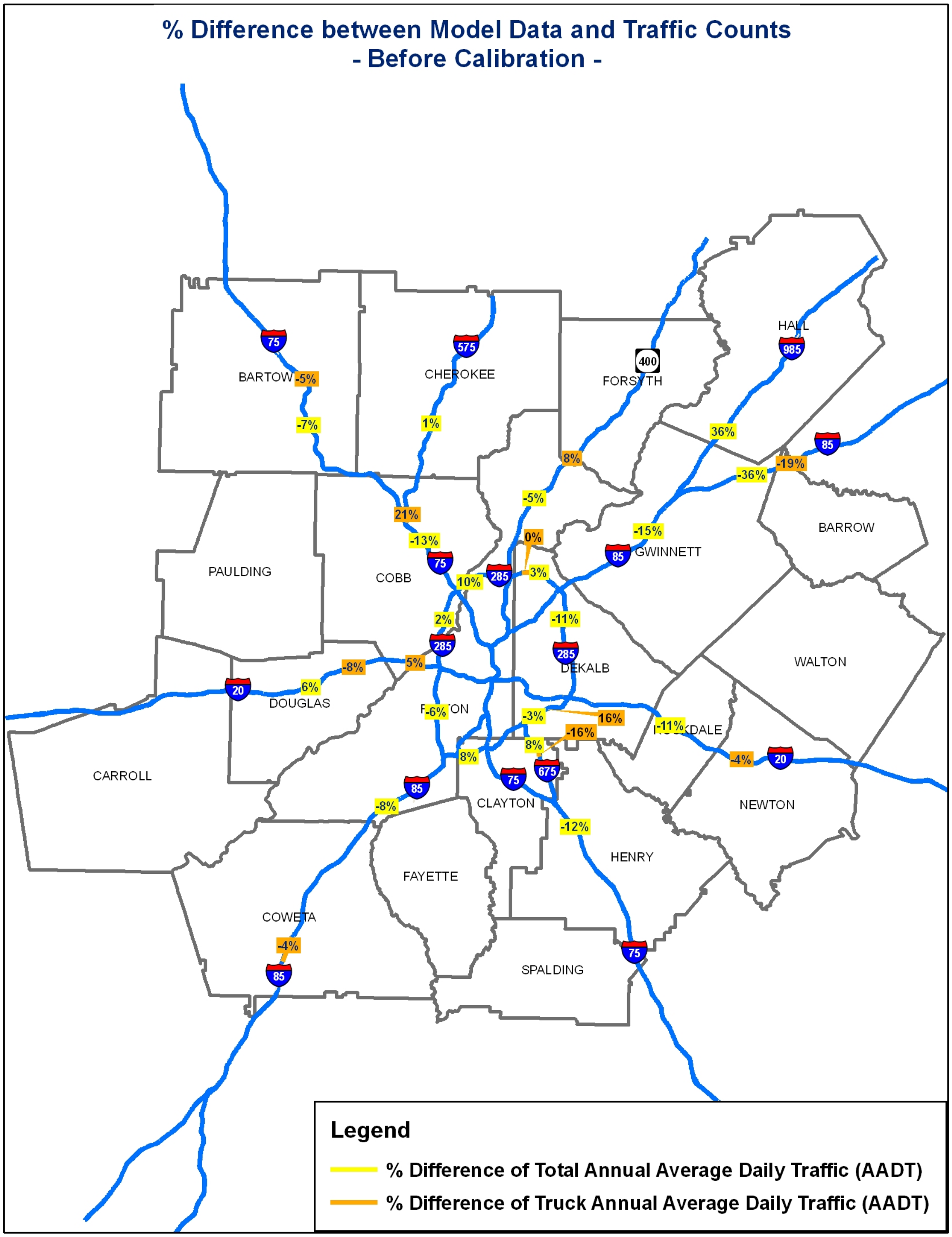


Figure 4-4: Comparison of 2005 Model Data and GDOT Counts Data - Before Calibration

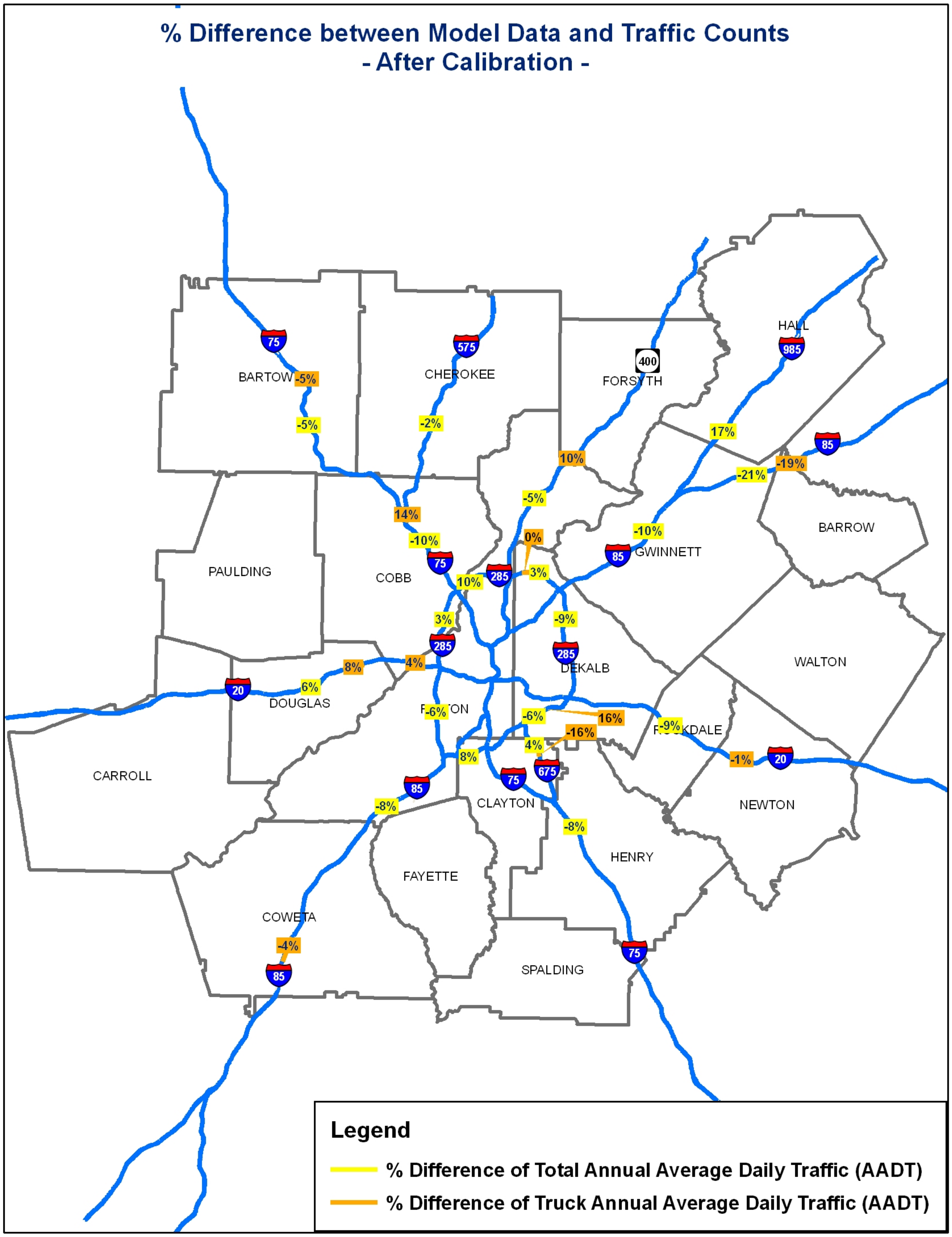


Figure 4-5: Comparison of 2005 Model Data and GDOT Counts Data - After Calibration

Since there are no available future-year observed data to calibrate a future year model, this research assumes that model parameters such as population and employment growth rates, number and size of traffic analysis zones, and highway network improvements from the region's transportation plan will not change over time from those assumptions made in the ARC 2030 plan. The validated 2030 ARC travel demand model is used to forecast traffic conditions of GP lanes and performance measures of potential TOT lanes.

4.3. Screening Criteria of TOT Lanes

Corridors that meet the following four criteria regarding deficiency in operational efficiency and viability in financing are considered for potential TOT lanes: heavy congestion, high truck volume, high truck percentage, and cost of truckers' willingness-to-pay less than monetary value of travel time savings. In addition to these four primary criteria, a secondary criterion of a high truck-related crash rate is used to identify candidates for safety improvements.

4.3.1. Level of Service

Level of service (LOS) is a qualitative measure of traffic operational conditions, ranging from A to F. The highway capacity manual (HCM) describes the six levels of LOS depicted as follows (TRB 2000): (1) LOS A represents free-flow conditions, (2) LOS B represents reasonably free-flow conditions of low-density traffic, (3) LOS C represents medium-density traffic flow conditions, (4) LOS D represents high-density traffic flow conditions, (5) LOS E represents traffic operations at or near capacity, and (6) LOS F represents traffic operations beyond capacity. The volume-to-capacity (V/C) ratio is a quantitative measure of LOS. This research defines V/C ratios that represent different LOS based on Georgia DOT's standards (GDOT 2006), as shown in Table 4-3. A V/C ratio greater than or equal to 1.0 indicates serious congestion of LOS F. A V/C ratio between 0.85 and 1.0 indicates moderate congestion of LOS E. Both LOS E and F are considered unacceptable traffic operational conditions.

In general, the PM peak period experiences heavier traffic congestion than other time periods. Severe traffic congestion that causes longer travel times and less reliable trip times provide an incentive for truckers to select congestion-free routes. Therefore, one of the screening criteria for candidate TOT lanes is LOS E or F on general purpose lanes during the PM peak period in the projected year 2030. Corridors that meet this criterion are shown in Figure 4-6.

Table 4-3: Level of Service and Volume-to-Capacity Ratio

Level of Service (LOS)	Volume-to-Capacity (V/C) Ratio
A-B	<= 0.5
C	0.5 ~ 0.7
D	0.7 ~ 0.85
E	0.85 ~ 1.0
F	>= 1.0

Source: GDOT, Travel Demand Model Development Guide, 2006

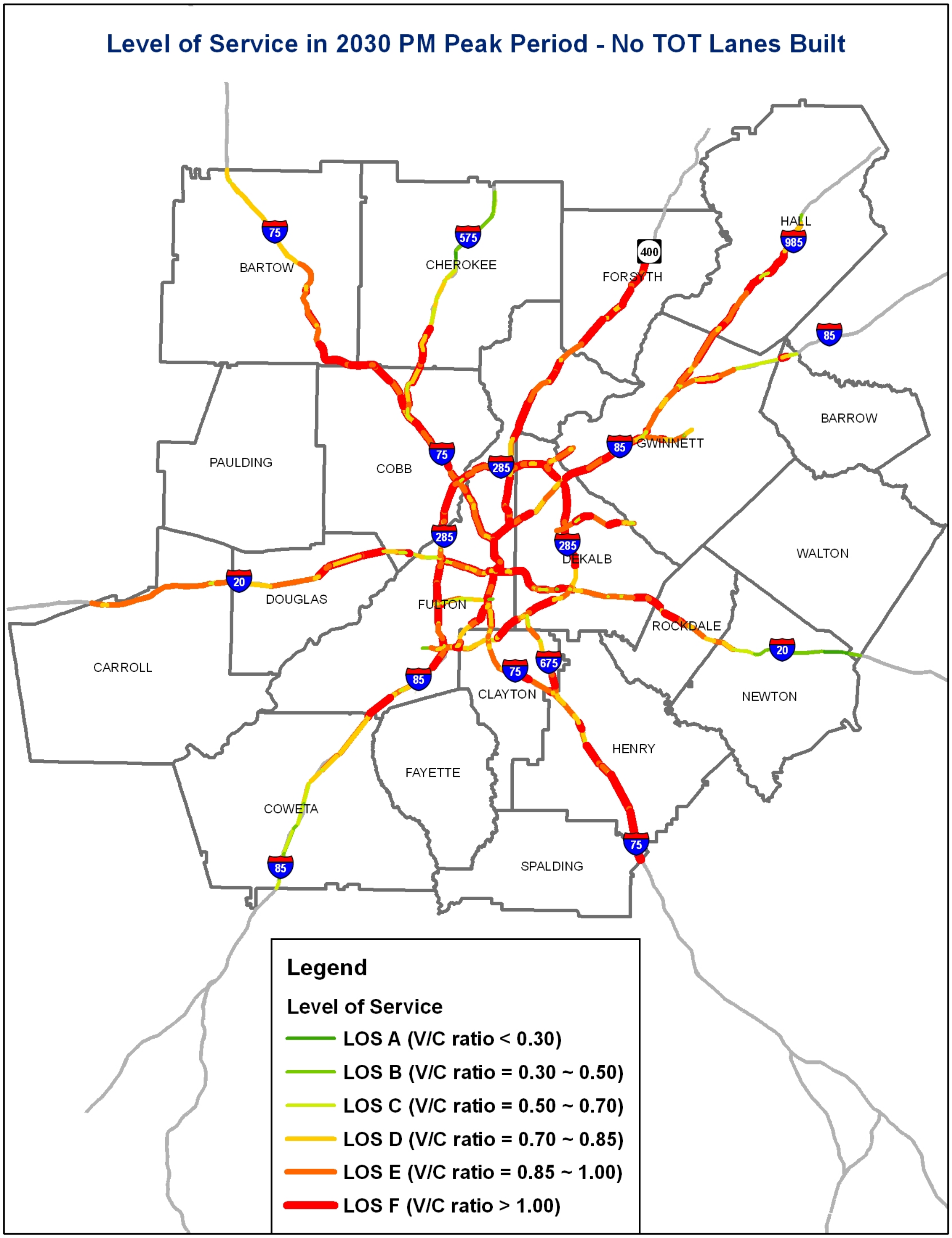


Figure 4-6: Forecast Level of Service on Atlanta Regional Interstates (PM Peak)

4.3.2. High Truck Volume

In addition to the large volume of truck traffic during peak periods, a lot of trucks choose off-peak periods to move freight and avoid severe congestion. For example, local truck deliveries usually choose the midday off-peak period to avoid travel time delays in urban areas. Therefore, this methodology uses daily truck volumes which include morning, afternoon, midday, and night truck volumes as one of the screening criteria for TOT lanes.

Higher truck volumes have more significant impact on the generation of toll revenues which creates a self-financing opportunity for TOT lanes. The mean daily truck volume (medium and heavy trucks) in each direction on Atlanta regional interstate highways in the projected year 2030 is approximately 10,000. The cumulative distribution curve shows that truck volumes greater than 9,000 account for 50% of selected highway links, as shown in Figure 4-7. If a higher volume such as the 90th percentile in regional interstates is used as a threshold value, then fewer links are selected and some links with potential revenues generation are likely to be excluded. Similarly, if a lower volume such as the 10th percentile is used as a threshold value, more links are selected, but those links may not be able to generate enough revenues because of low volumes. It is appropriate to select at least the top half of regional highway links with high truck volumes to justify the utilization of TOT lanes. Therefore, this research uses a threshold value of 9,000 daily truck volumes to evaluate a sufficient truck travel demand for candidate TOT lanes. The threshold value will vary by metropolitan areas because of different truck flows. Corridors which meet this criterion are shown in Figure 4-8.

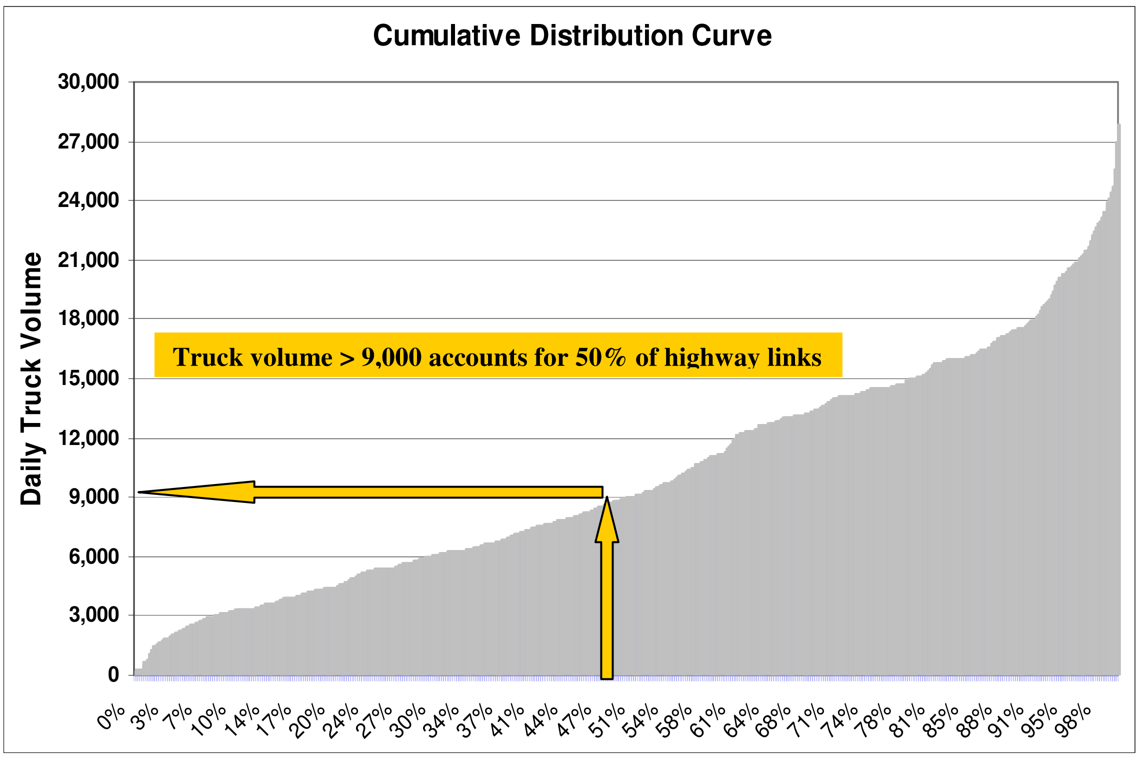


Figure 4-7: Cumulative Distribution of Daily Truck Volume (Medium + Heavy)

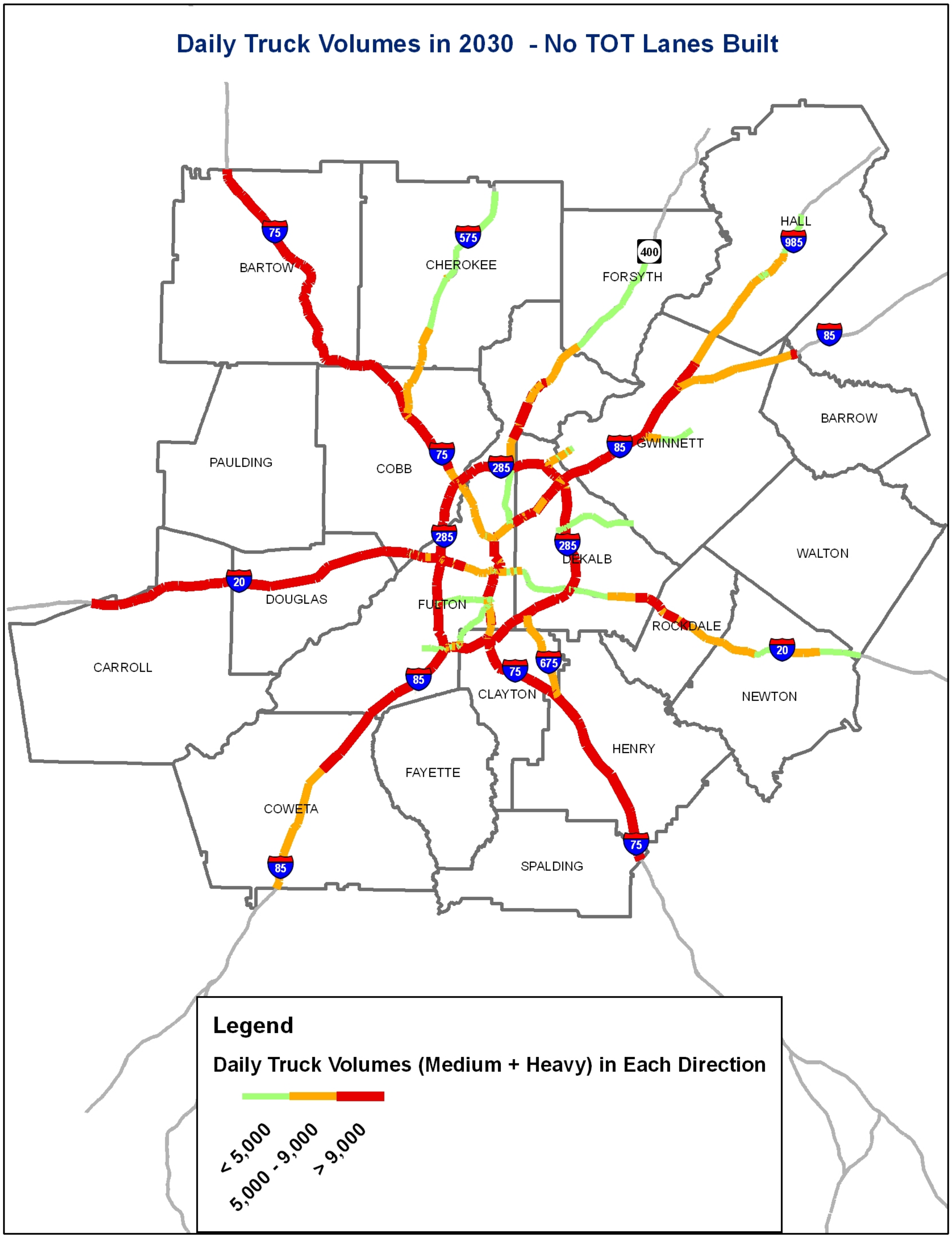


Figure 4-8: Forecast Daily Truck Volumes on Atlanta Regional Interstates

4.3.3. High Truck Percentage

A higher truck percentage has more significant impact on traffic operational conditions such as severe traffic congestion and increased truck-related crashes on interstate highways. TOT lanes separate from general purpose lanes can provide the benefits of reduced congestion and crashes. The mean daily truck percentage (medium and heavy trucks) in each direction on Atlanta regional interstate highways in the projected year 2030 is approximately 15% of all traffic. The cumulative distribution curve shows that truck percentages greater than 14% account for 50% of selected highway links, as shown in Figure 4-9. If a higher percentage such as the 90th percentile in regional interstates is used as a threshold value, then fewer links are selected and some links with potential needs for traffic condition improvements are likely to be excluded. If a lower percentage is used as a threshold value, more links are selected, but those links may not need additional truck lanes because of already acceptable traffic conditions. It is appropriate to select at least the top half of regional highway links with a high truck percentage to justify the operational efficiency of TOT lanes. Therefore, the methodology uses a threshold value of 14% to evaluate an adequate truck traffic percentage for candidate TOT lanes. The threshold value will vary by metropolitan areas because of different truck percentage data. Corridors which meet this criterion are shown in Figure 4-10.

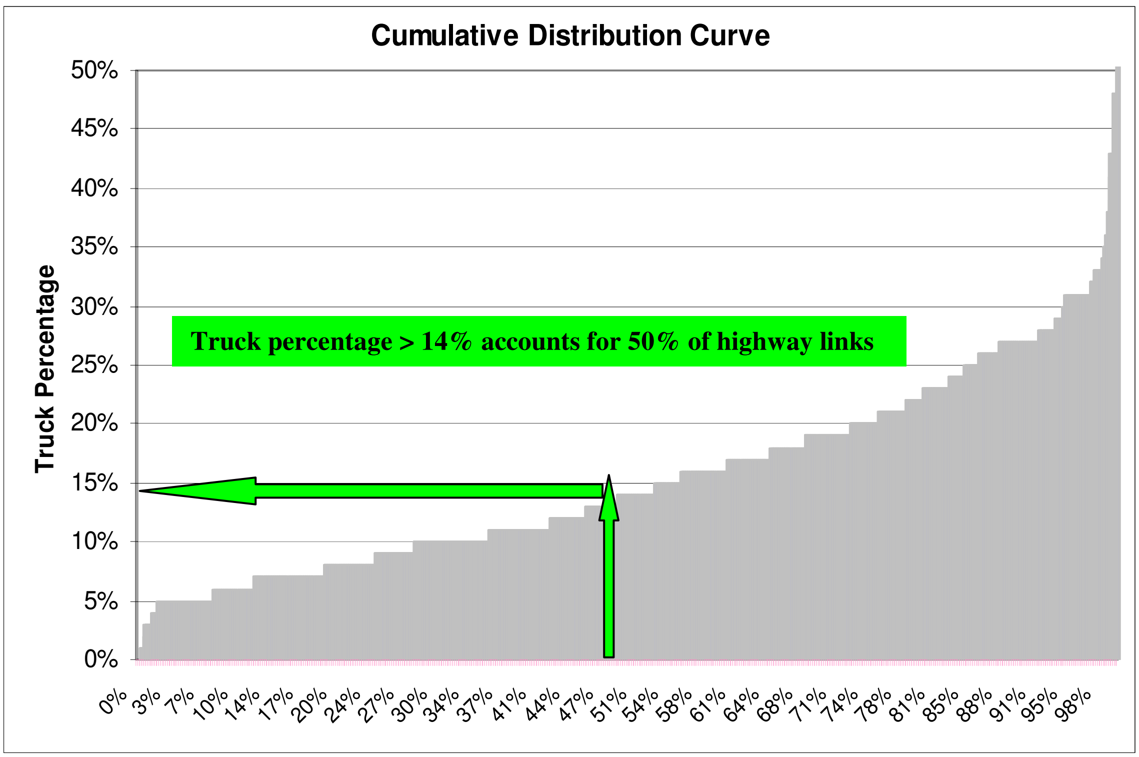


Figure 4-9: Cumulative Distribution of Truck Percentage

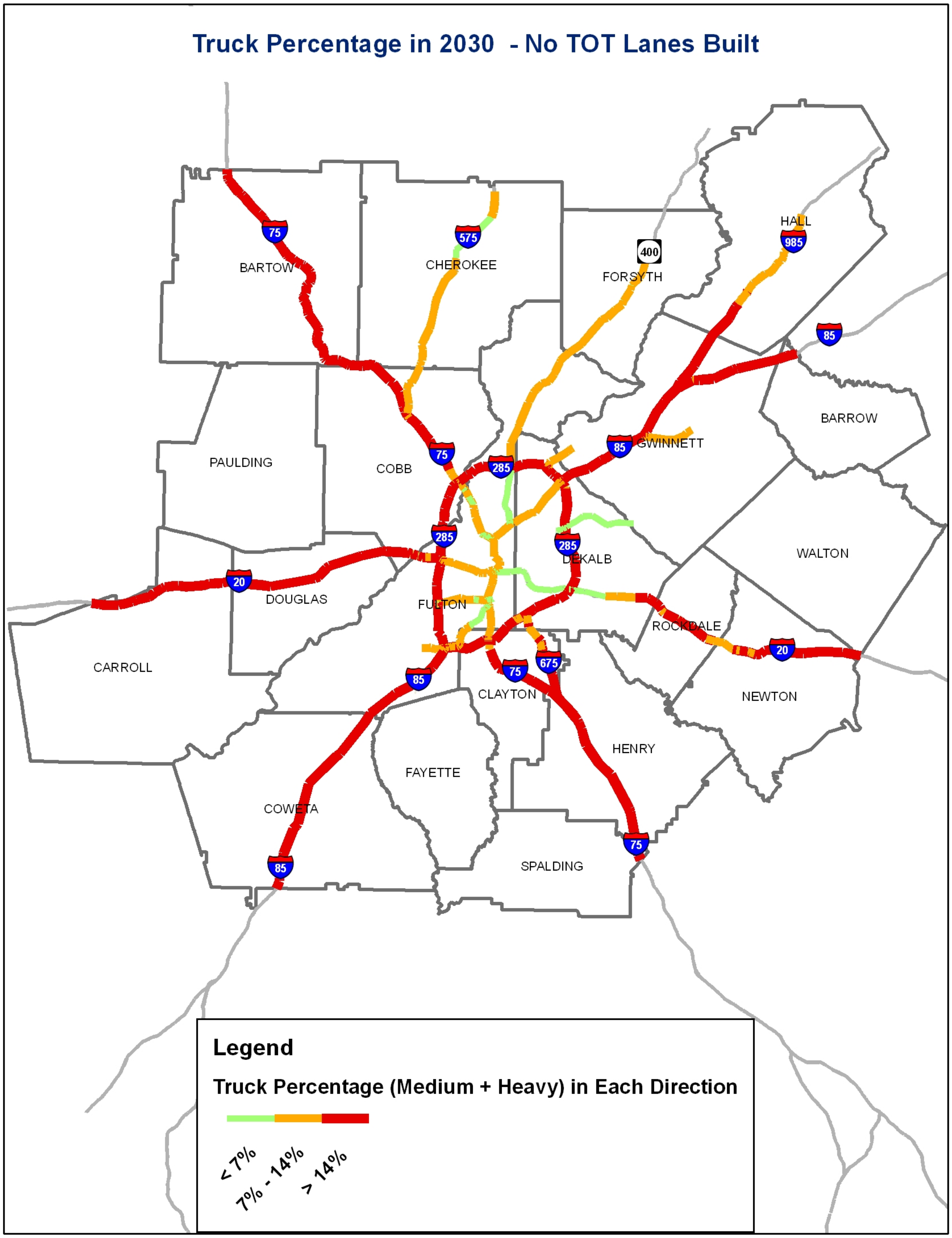


Figure 4-10: Forecast Daily Truck Percentage on Atlanta Regional Interstates

4.3.4. High Truck-Related Crashes

TOT lanes can significantly reduce fatal and serious injury crashes involving heavy trucks because of the separation of trucks from the mixed traffic flow. Therefore, a high truck-related crash location is considered as a good candidate for building TOT lanes to improve safety. As noted in Chapter 3, an interstate segment that experiences over the average regional truck-related crash rate of 63 crashes per 100 million VMT is identified as a high truck-related crash location. This criterion is used to evaluate the need for safety improvements if building TOT lanes. This research identifies existing high truck-related crash locations on Atlanta interstate highways and identifies corridors with a safety deficiency including I-75 north, I-285 perimeter, I-75 south, I-20 west, I-85 north, and I-85 south, as shown in Figure 4-11.

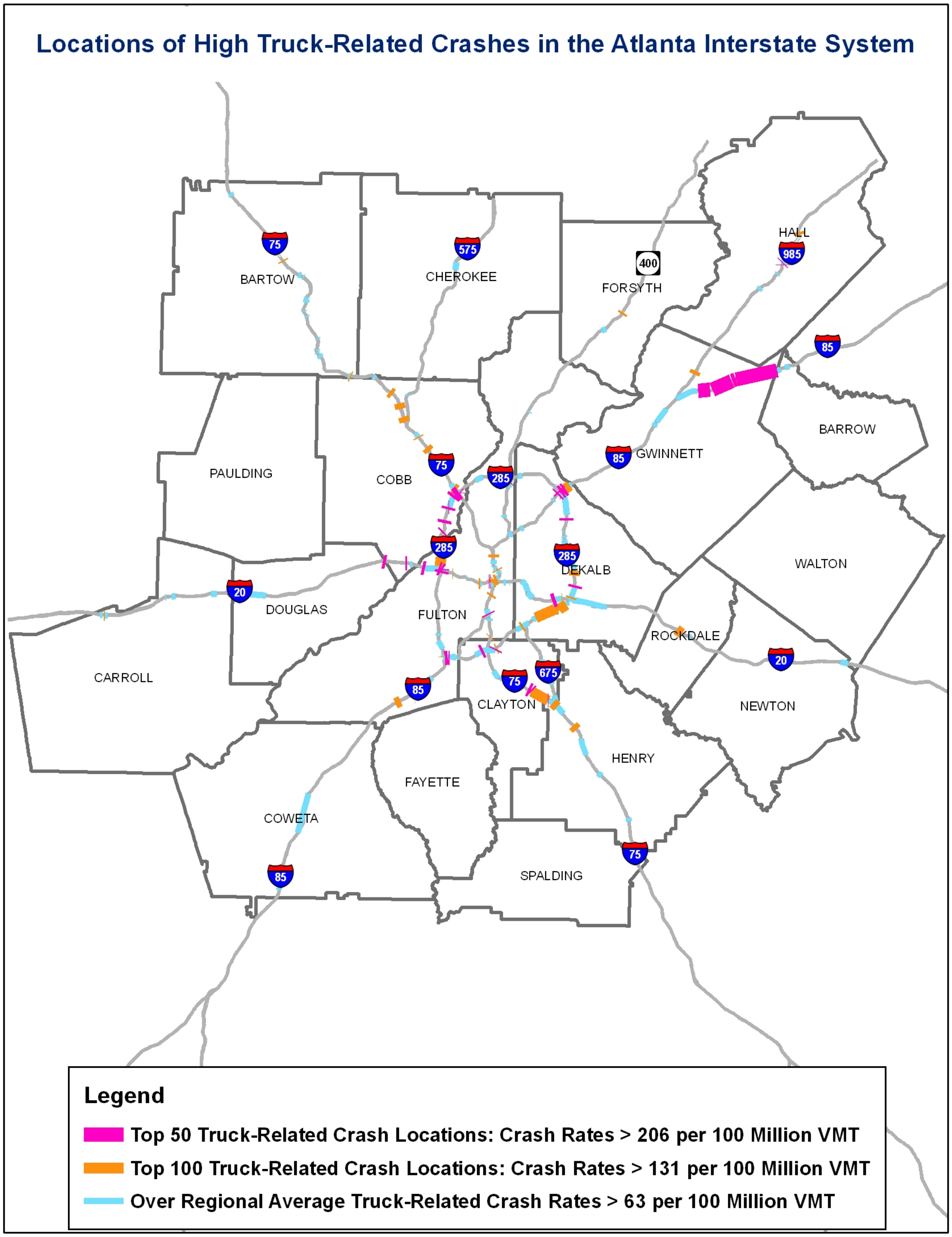


Figure 4-11: Locations of Existing High Truck-Related Crashes on Atlanta Regional Interstates

4.3.5. Trucker's Cost Saving Threshold

To justify TOT lane usage, the methodology uses truckers' willingness-to-pay data to examine the truckers' likelihood of using voluntary TOT lanes based on the trade-off between toll costs and travel time savings. This research defines as a cost saving threshold (CST) which means the minimum value of cost savings that must be obtained for the truckers to be willing to pay a toll. The travel time saved by using a TOT lane will depend on the speed in the TOT lane. If a highway segment experiences congested travel speed and can benefit in travel time savings by providing at least the average travel speed of the corridor during the PM peak period in the projected year 2030, then this segment is selected as a potential TOT lane. This was considered a conservative target in that the value of time saved would be much less than that likely to be achieved if the TOT lane was at free flow speed.

Based on the previous data collection described in Chapter 3, the average truckers' value of time is \$31/hr and the willingness-to-pay of 90% of all trucks is \$3. For purposes of the screening process, a threshold value at the 90th percentile level or a value of \$3 is chosen for the screening criterion. For example, if the monetary value of travel time saved on a highway link is \$2.00, and the 90th percentile minimum cost savings threshold was at least \$3.00 in savings for trucks to use a tolled lane, this segment would not be a candidate for a TOT lane. The target of average corridor speed was considered a rather conservative assumption. One could establish through policy a desired TOT lane speed in the corridor much higher than the average corridor speed during the PM peak. Figure 4-12 illustrates highway network links meet this criterion. The other threshold values of 80th, 70th, 60th, and 50th refer to different scenarios will be discussed in a later section 4.3.7.

This criterion is defined as follows.

If $CST_{\mathbf{i,\ 90\%}} < C_{\mathbf{i}}$, then segment i would be selected as a potential TOT lane

where,

$CST_{\mathbf{90\%}}$ (\$) = 90$^{\mathbf{th}}$ percentile cost savings threshold

$CST_{i,\,90\%}$ (\$) = $CST_{90\%} \times (L_i / \sum_{i=1}^{n} Li)$ = Percent of cost savings threshold applicable to link i

VOT_{avg} (\$/hr) = Truckers' average value of time

SP_i (mile/hr) = Segment i travel speed

L_i (mile) = Segment i length

SP_{avg} (mile/hr) = $\sum_{i=1}^{n} Li \;/\; \sum_{i=1}^{n} (Li/SPi)$ = Corridor average travel speed over n segments

TTS_i (hr) = $L_i \times (1/SP_i - 1/SP_{avg})$ = Travel time difference in providing segment i with the corridor average travel speed, where $SP_i < SP_{avg}$

C_i(\$) = $TTS_i \times VOT_{avg}$ = Monetary value of travel time saved on segment i

4.3.6. Combining the Screening Criteria

The five screening criteria are used to determine the extent/boundary of feasible TOT lane corridors. Seven corridors in the Atlanta region which meet these screening criteria are identified as potential TOT lane corridors, as shown in Table 4-4 and Figure 4-13. Considering the connection of regional interstate systems and locations of ingress and egress, the boundary of TOT corridors will be extended to system interchanges. In addition, most of the selected potential TOT corridors are consistent with the locations of the current largest warehouses and distribution centers in the Atlanta region, as shown in Figure 4-14 (Atlanta Advancing Logistics 2006).

Table 4-4: Potential TOT Lane Corridors on Atlanta Regional Interstates

Screening Criteria	Potential TOT Corridors	
1. Level of service (pm peak) = E ~ F	1.	I-75 N (from I-285 N to SR 20 in Bartow county)
2. Truck volume (daily) > 9,000	2.	I-85 N (from I-285 N to I-85@I-985 in Gwinnett county)
3. Truck percentage (daily) > 14%	3.	I-285 Perimeter
4. Truck-related crash rate (annual) > average regional crash rate	4.	I-20 E (from I-285 E to SR 138 in Rockdale county)
5. Travel time savings (pm peak) > 90th percentile truckers' cost saving threshold	5.	I-20 W (from I-285 W to Atlanta regional boundary in Carroll county)
	6.	I-85 S (from I-285 S to SR 154 in Coweta county)
	7.	I-75 S (from I-285 S to Atlanta regional boundary in Spalding county)

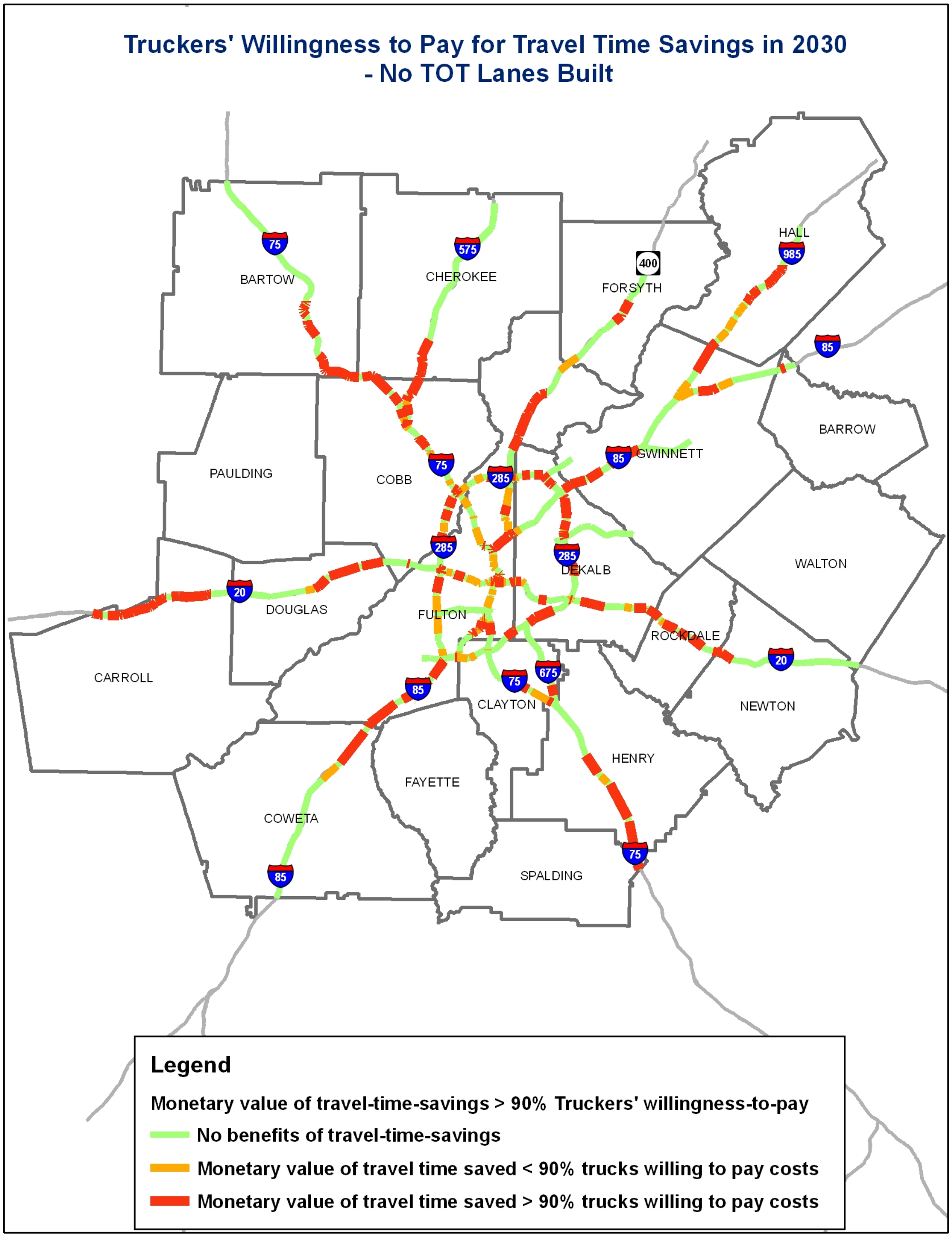


Figure 4-12: Forecast Highway Links Meet 90% Truckers' Costs Saving Threshold on Atlanta Regional Interstates

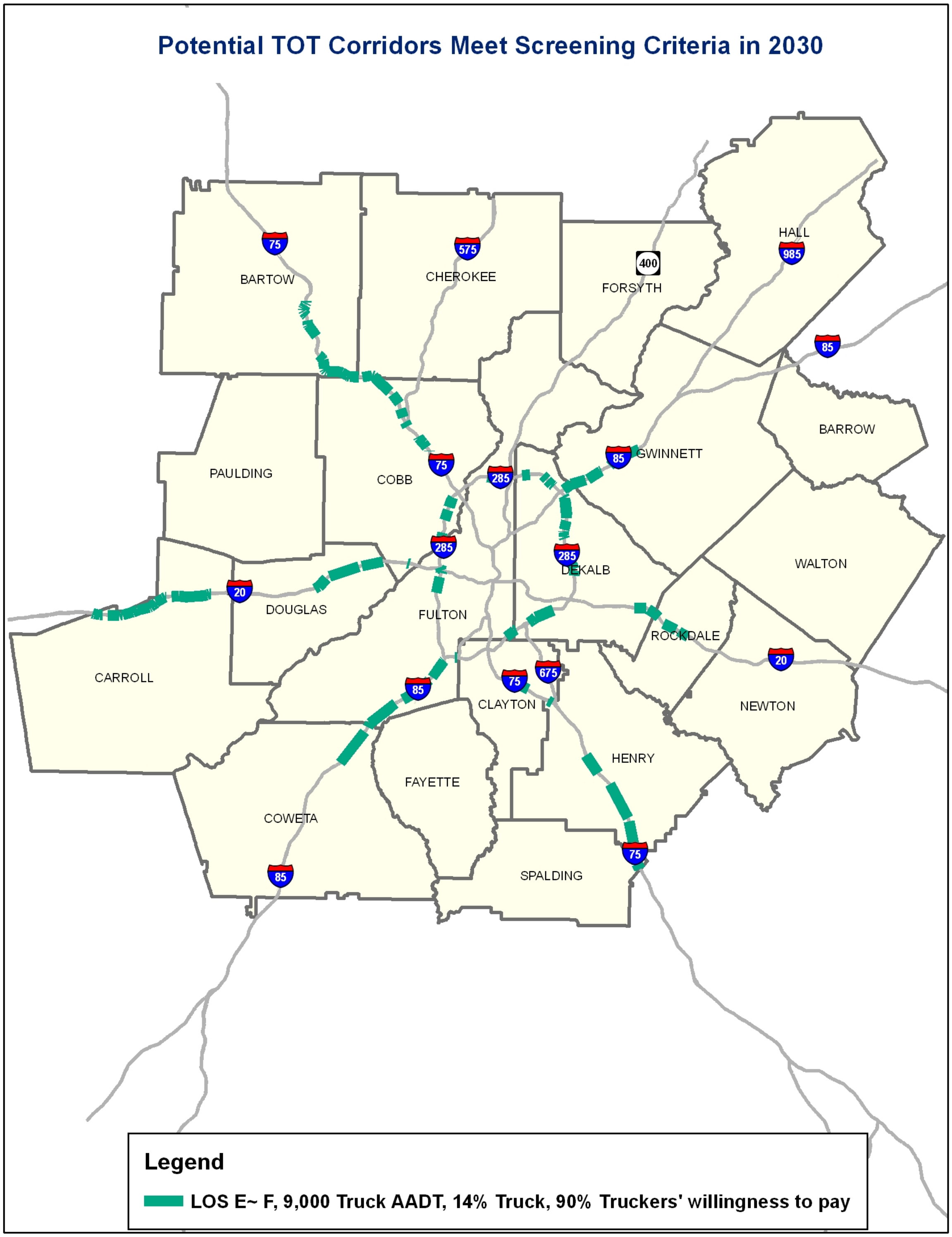


Figure 4-13: Potential TOT Lane Corridors Selected by Screening Criteria on Atlanta Regional Interstates

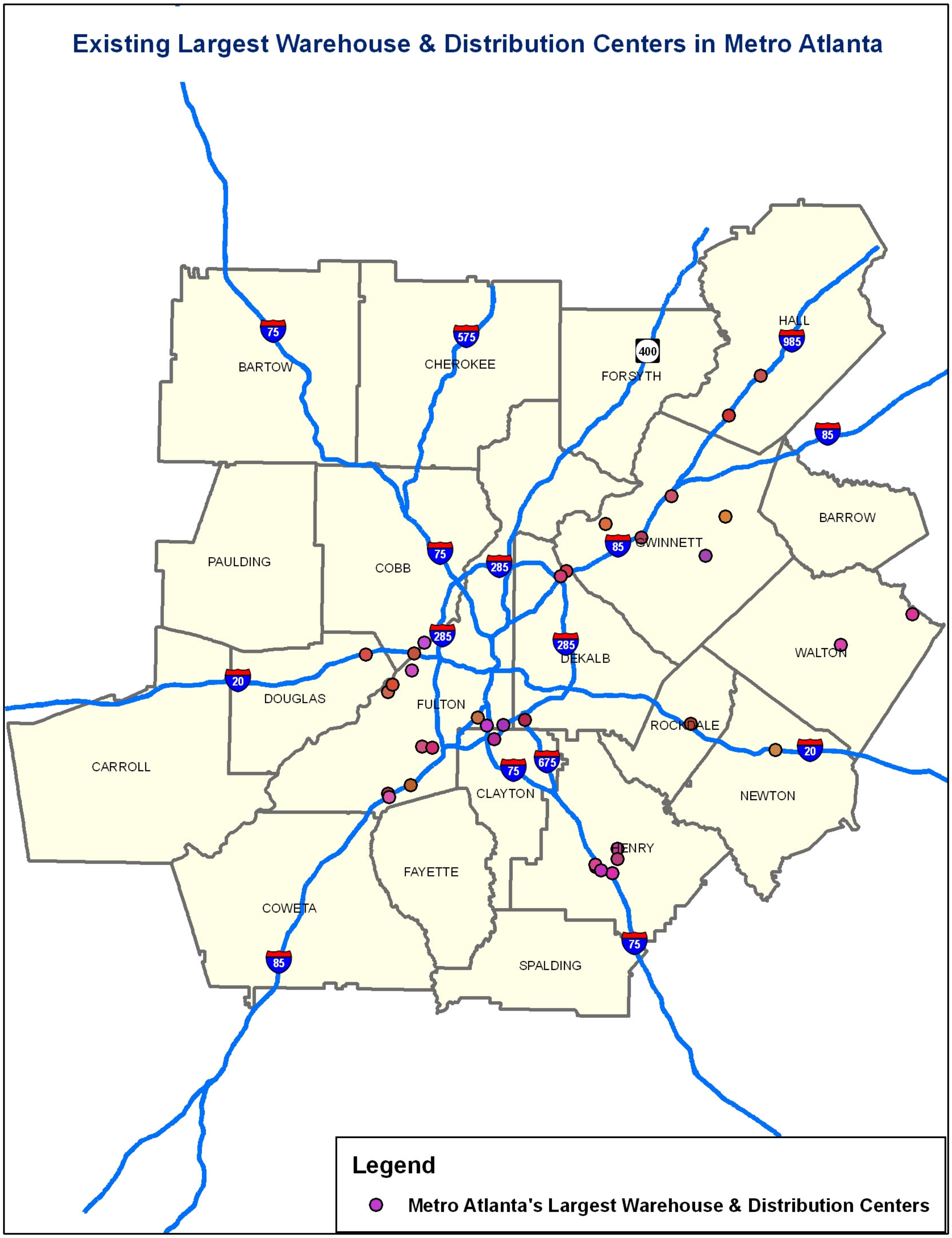


Figure 4-14: Current Largest Warehouses and Distribution Centers in the Atlanta Region

4.3.7. Sensitivity of Corridor Selection to Willingness-to-Pay

In addition to the requirement that at least 90% of truckers' willingness-to-pay toll costs less than the monetary value of travel time savings, this research conducted sensitivity tests of different percentages of truckers' willingness-to-pay to incorporate potential variation in candidate TOT lanes. Four scenarios including 80%, 70%, 60%, and 50% of truckers' willingness-to-pay are analyzed as follows and illustrated in Figure 4-15.

Scenario 1: More than 80% of truckers' willingness-to-pay less than the monetary value of travel time savings. If the criterion is changed to 80% of trucks are willing to pay costs of \$7.0 to use TOT lanes, then 161 fewer links qualify as TOT lane candidates, as shown in Figure 4-16. Concerning the potential TOT corridors that meet all criteria simultaneously, there are 68 fewer links than when using the 90% willingness-to-pay criterion. These removed links located on all Atlanta freeways and including at the edge of some corridor boundaries. Therefore, the elimination of these links located at the corridor edges shortens the extent/boundary of potential TOT lane corridors, with the exception of the I-20 east, I-20 west, I-85 south, and I-75 south corridors, as shown in Figure 4-17.

Scenario 2: More than 70% of truckers' willingness-to-pay less than the monetary value of travel time savings. If the criterion is changed to 70% of trucks are willing to pay costs of \$9.5 to use TOT lanes, then 224 fewer links qualify as TOT lane candidates, as shown in Figure 4-18. Regarding the potential TOT corridors that meet all criteria simultaneously, there are 107 fewer links than when using the 90% willingness-to-pay criterion. These removed links located on all Atlanta freeways and including at the edge of most corridor boundaries. Therefore, the elimination of these links located at the corridor edges shortens the extent/boundary of potential TOT lane corridors, with the exception of the I-20 east corridor, as shown in Figure 4-19.

Scenario 3: More than 60% of truckers' willingness-to-pay less than the monetary value of travel time savings. If the criterion is changed to 60% of trucks are willing to pay costs of \$12.5 to use TOT lanes, then a total of 261 fewer links qualify as TOT lane candidates, as shown in Figure 4-20. Regarding the potential TOT corridors that meet all criteria simultaneously, there are 123 fewer links than when using the 90% willingness-to-pay criterion. These removed links located on all Atlanta freeways and including at the edge of the corridor boundaries. Therefore, the elimination of these links located at the corridor edges shortens the extent/boundary of potential TOT lane corridors, as shown in Figure 4-21.

Scenario 4: More than 50% of truckers' willingness-to-pay less than the monetary value of travel time savings. If the criterion is changed to 50% of trucks are willing to pay costs of \$15.4 to use TOT lanes, then a total of 297 fewer links qualify as TOT lane candidates, as shown in Figure 4-22. Regarding the potential TOT corridors that meet all criteria simultaneously, there are 147 fewer links than when using the 90% willingness-to-pay criterion. These removed links located on all Atlanta freeways and including at the edge of the corridor boundaries. Therefore, the elimination of these links located at the corridor edges shortens the extent/boundary of potential TOT lane corridors, as shown in Figure 4-23.

Based on the assessment of these scenarios, 90% willingness-to-pay covers the largest service range and makes significant difference among 50%, 60%, 70%, and 80% willingness-to-pay assumptions in the selection of potential TOT lanes. Considering the connectivity of interstate systems, the boundary of TOT lanes on the I-85N corridor is better extended to the system interchange at I-985 instead of the regular interchange at SR 316. This research adopts a 90% willingness-to-pay criterion as one of the TOT lane screening criteria to study the feasibility of TOT lanes in the Atlanta regional interstate system.

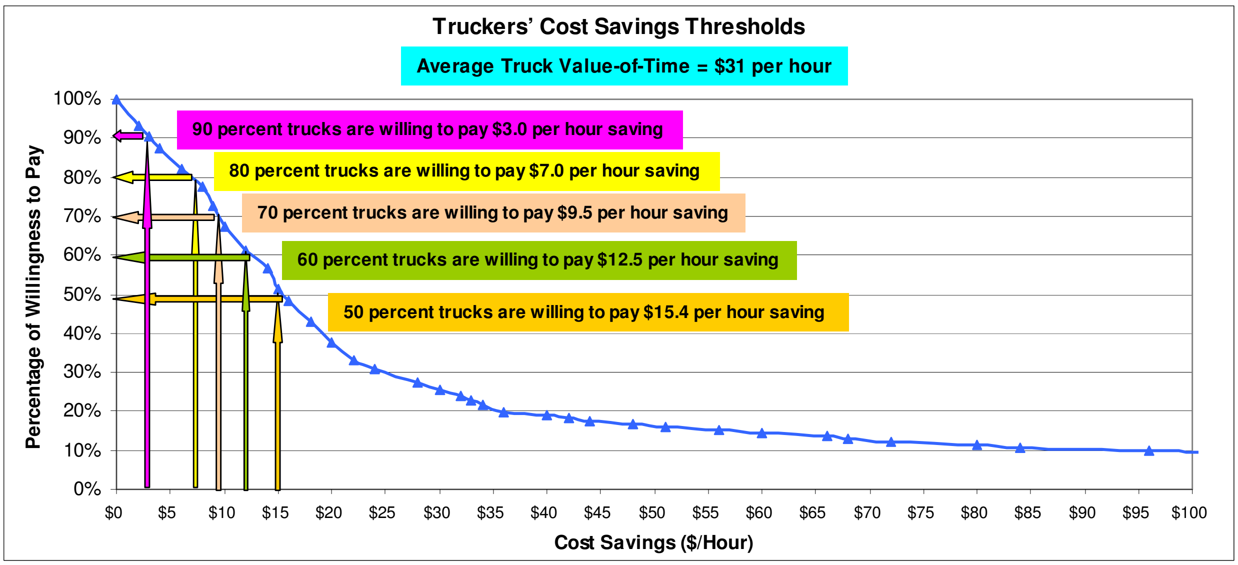


Figure 4-15: Percentage of Truckers' Trip Cost Saving Distribution

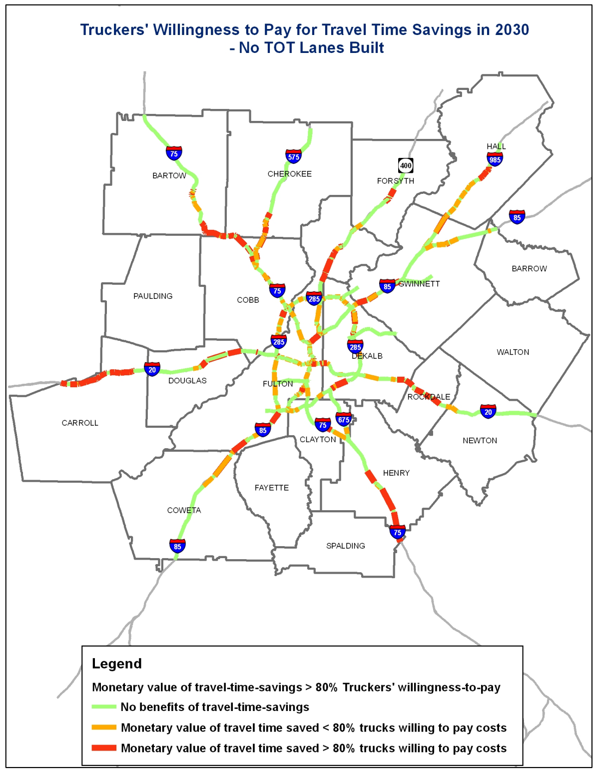


Figure 4-16: Forecast Highway Links Meet 80% Truckers' Costs Saving Threshold

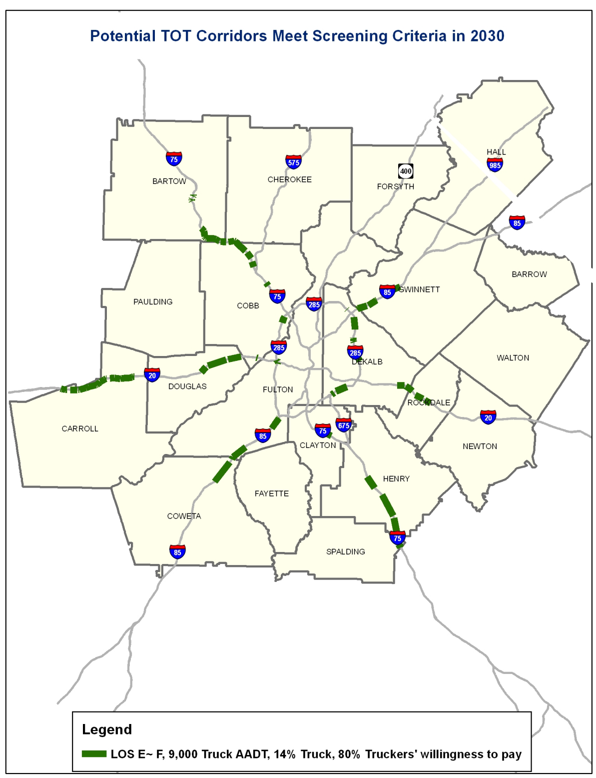


Figure 4-17: Potential TOT Corridors Based on 80% Truckers' Costs Saving Threshold

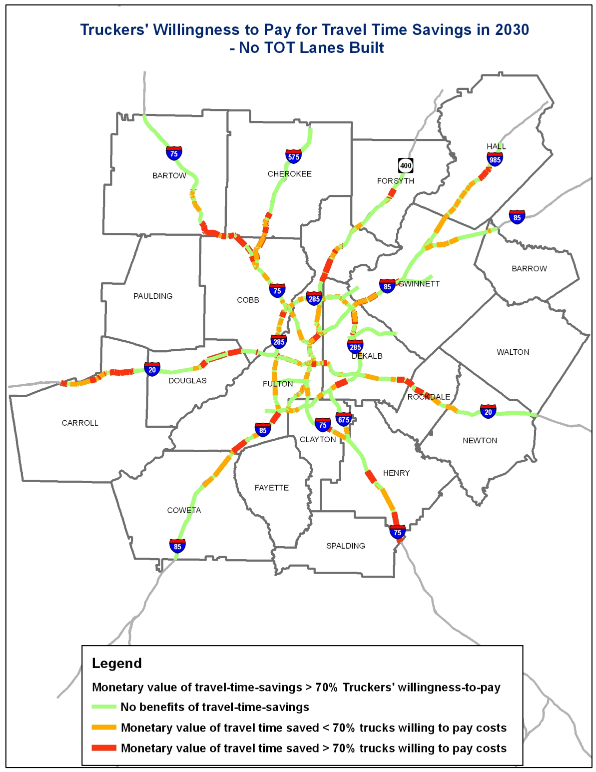


Figure 4-18: Forecast Highway Links Meet 70% Truckers' Costs Saving Threshold

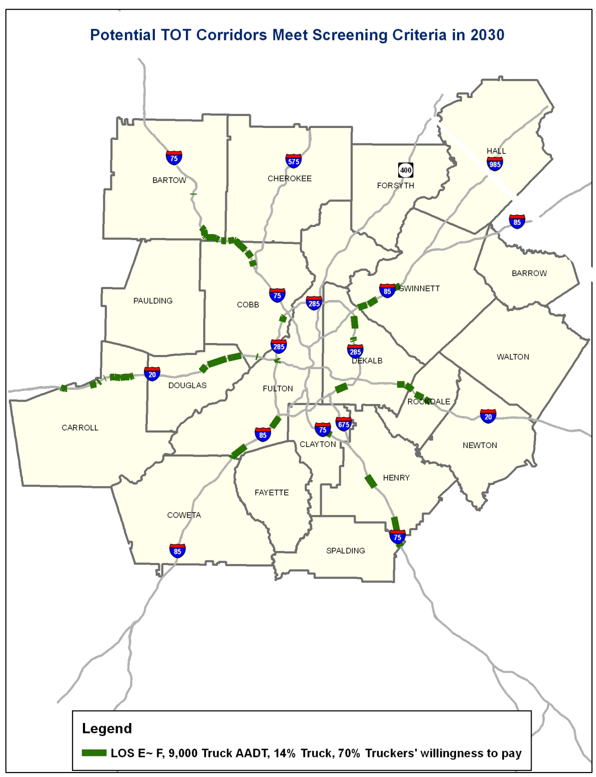


Figure 4-19: Potential TOT Corridors Based on 70% Truckers' Costs Saving Threshold

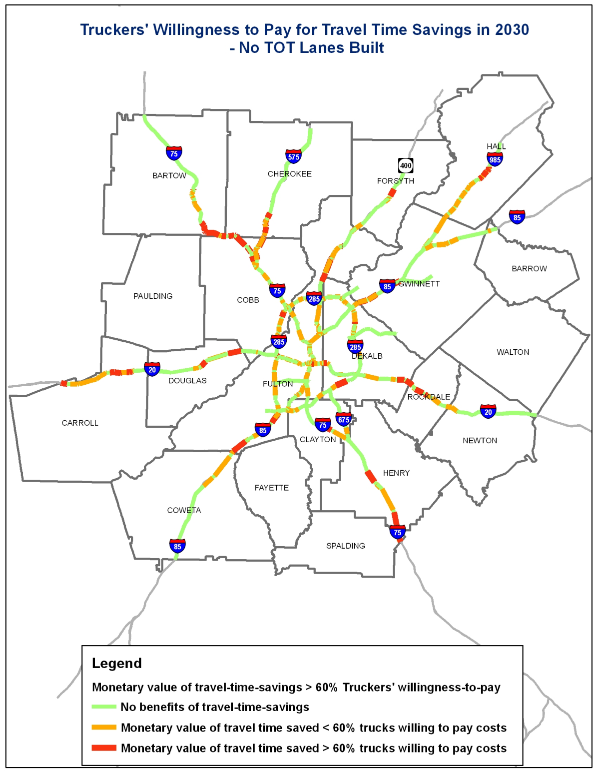


Figure 4-20: Forecast Highway Links Meet 60% Truckers' Costs Saving Threshold

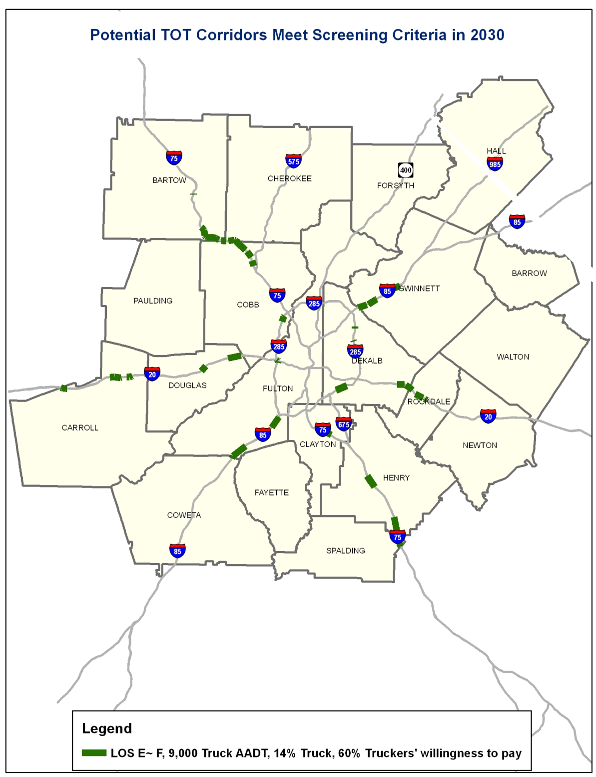


Figure 4-21: Potential TOT Corridors Based on 60% Truckers' Costs Saving Threshold

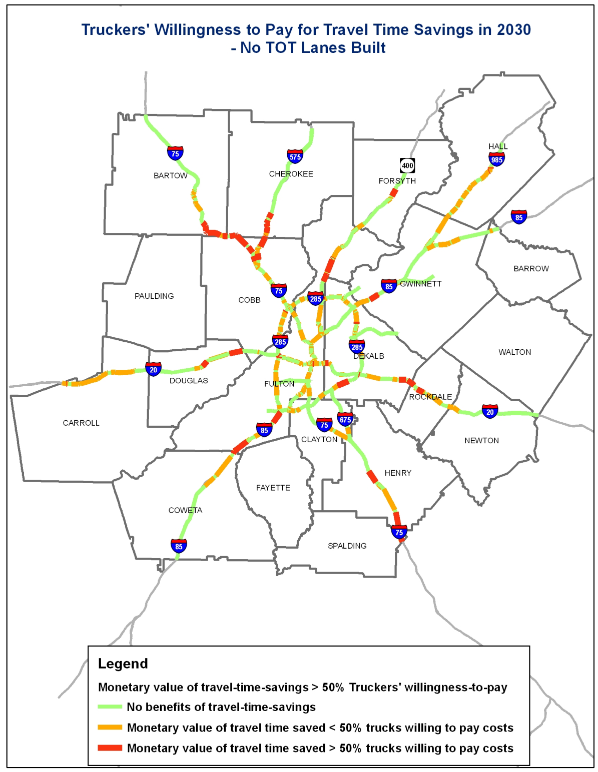


Figure 4-22: Forecast Highway Links Meet 50% Truckers' Costs Saving Threshold

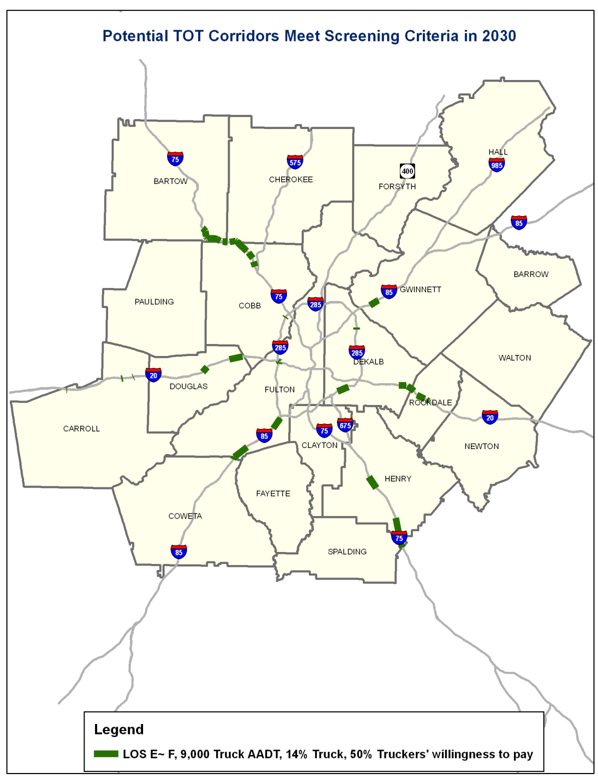


Figure 4-23: Potential TOT Corridors Based on 50% Truckers' Costs Saving Threshold

4.4. Engineering Feasibility Criteria for TOT Lane Locations

The engineering feasibility of TOT lane placement is based on the following criteria: (1) the percentage of through truck traffic traveling along the corridor, (2) the need to relocate existing HOV lanes, and (3) the acquisition of right of way.

4.4.1. Through Truck Volume

TOT lanes located at the inside (leftmost) lanes are appropriate for large through truck traffic or long distance truck trips, where the trip origin and destination are outside the corridor. Engineering costs can be reduced for building access ramps between starting and ending points within a corridor because through trucks do not enter or exit at every interchange. TOT lanes located at the outside (rightmost) lanes are appropriate for local truck traffic or short distance truck trips, which need multiple access and egress points due to their trip origins or destinations within the corridor. The application of these two distinct design features improves traffic operating conditions and increases safety by reducing weaving conflicts between trucks driving through the corridor and cars getting on and off the interstate where exclusive access ramps are not built.

A select link analysis approach was used to identify truck trips that travel through a specific corridor in the model network. This approach can track truck trip origins/destinations and determine truck routes used by choosing the beginning and ending links of a corridor. For example, before building TOT lanes, approximately 80% of the forecasted daily heavy-truck flows on the I-75N (between I-285N and I-575) general purpose lanes will be through truck traffic in 2030. Also, approximately 70% of through heavy-truck trips have their origins or destinations outside the metro Atlanta region, as illustrated in Figure 4-24.

One of the key factors that influence the percentage of through truck traffic is the location of major freight generators along the corridor, which serve as an origin or destination for freight movements. For example, the low percentage of through truck volumes on I-20E, I-20W, I-985, I-85N (between I-285N and I-985), I-285E (between I-20E and I-75S), I-85S, and I-75S results from the location of several warehouse and distribution centers within these corridors. Similarly, the high percentage of through truck volumes on I-75N, I-285N, I-285W, I-285E (between I-20E and I-85N), I-85N (between I-985 and regional boundary), and I-675 results from the large amount of long-haul truck traffic that travels through these corridors. In addition, there is a low percentage of through truck volumes on I-575 and GA 400 because these corridors primarily serve local truck traffic instead of long-haul truck traffic, as illustrated in Table 4-5 and Figure 4-25 to Figure 4-33.

Based on an analysis of through truck traffic in each corridor, this research recommends that the threshold value for designing inside TOT lanes be based on a percentage of daily through heavy-truck volume greater than 50%. Meanwhile, direct access to the major freight generators must be considered. If through heavy-truck volume is less than 30%, outside TOT lanes or inside TOT lanes with multiple direct access interchanges would be a better option. As for the percentage of daily through truck traffic between 50% and 30%, the traffic engineer's judgment should be used to determine the inside or outside placement of TOT lanes.

Table 4-5: Percentage of Through Truck Traffic on Atlanta Regional Interstates in 2030

Corridor	From ~ To	% of Through Truck Volumes along Corridors	% of Trip OD outside the Atlanta Region
GA 400	I-285N ~ SR 20	28%	40%
I-575	I-75N ~ SR 20	30%	52%
I-75N I	I-285N ~ I-575	80%	70%
I-75N II	I-575 ~ SR 140	70%	97%
I-285N I	I-75N ~ GA 400	72%	30%
I-285N II	GA 400 ~ I-85N	90%	27%
I-85N I	I-285N ~ I-985	55%	75%
I-85N II	I-985 ~ SR 211	79%	94%
I-985	I-85N ~ SR 365	48%	58%
I-285W I	I-75N ~ I-20W	72%	63%
I-285W II	I-20W ~ I-85S	75%	44%
I-285S	I-75S ~ I-85S	80%	52%
I-285E I	I-85N ~ I-20E	60%	50%
I-285E II	I-20E ~ I-75S	40%	65%
I-85S	I-285S ~ Regional boundary	45%	97%
I-75S I	I-285S ~ I-675	30%	28%
I-75S II	I-675 ~ SR 16	6%	95%
I-20W	I-285W ~ US 27	40%	18%
I-20E	I-285E ~ US 278	9%	1%
I-675	I-285S ~ I-75S	80%	65%

Note: % of trip OD outside the Atlanta region means the percentage of through truck trips along a corridor originates or terminates outside the 20-county Atlanta region.

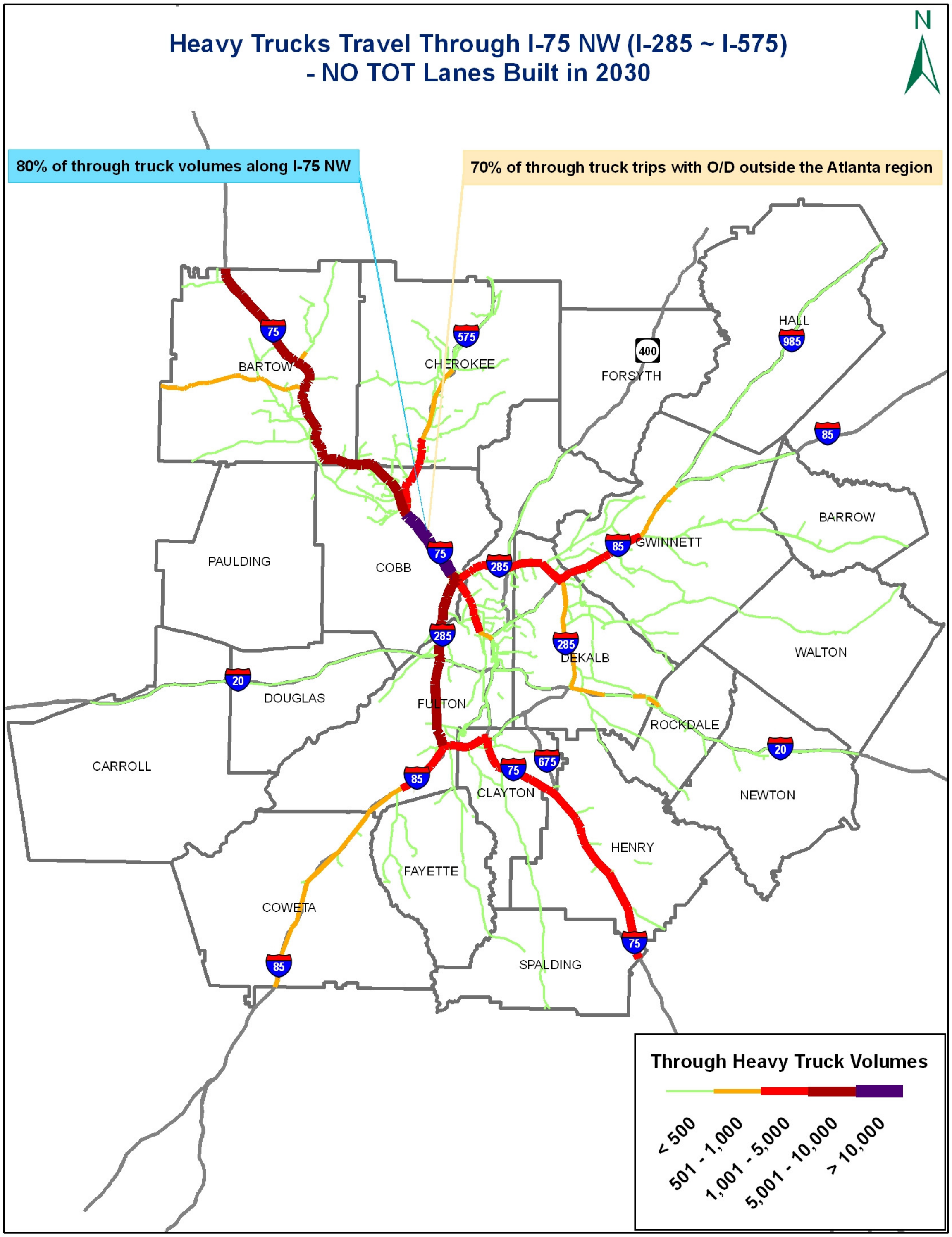


Figure 4-24: Heavy Truck Flows Travel Through I-75 NW (I-285 N ~ I-575)

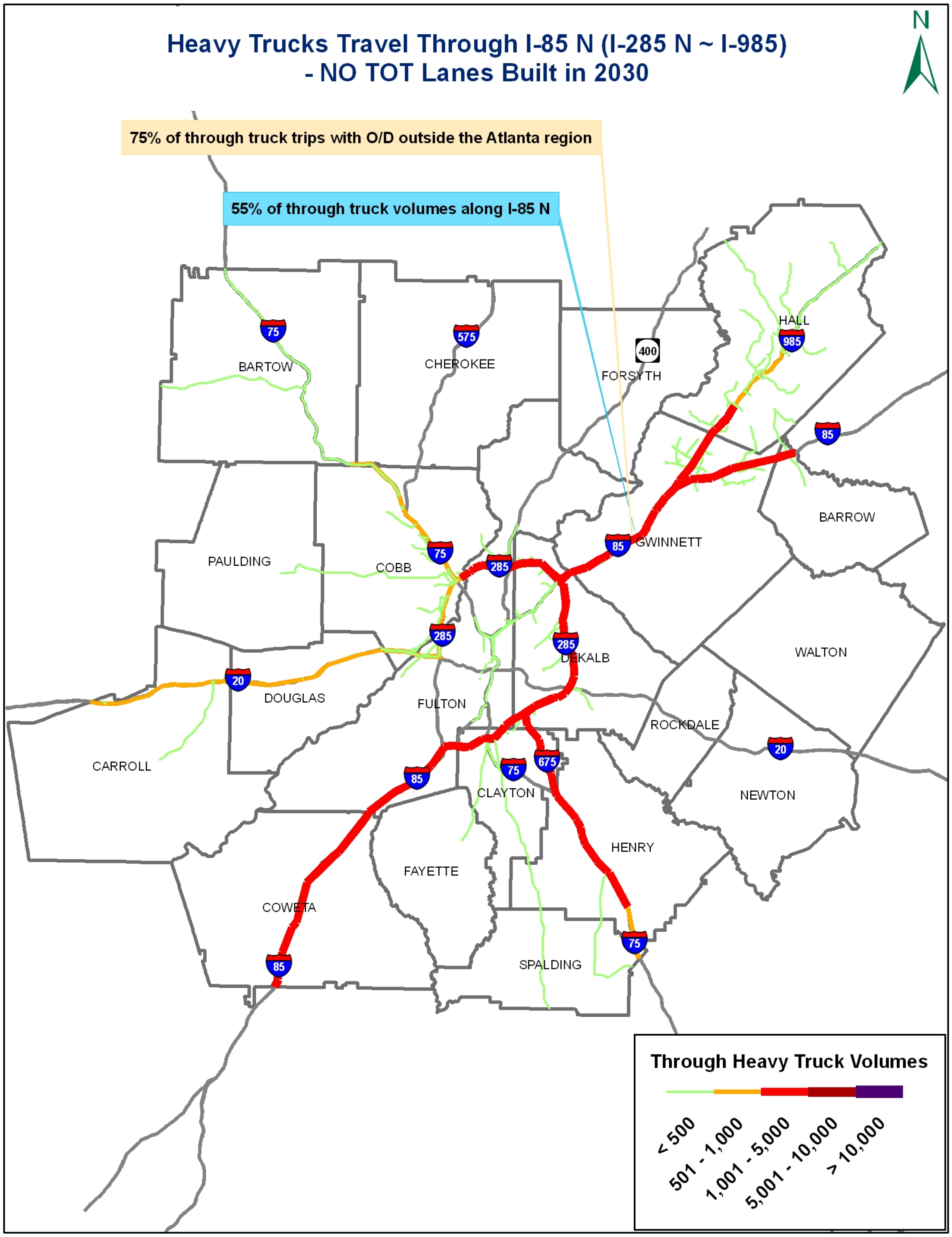


Figure 4-25: Heavy Truck Flows Travel Through I-85 N (I-285 N ~ I-985)

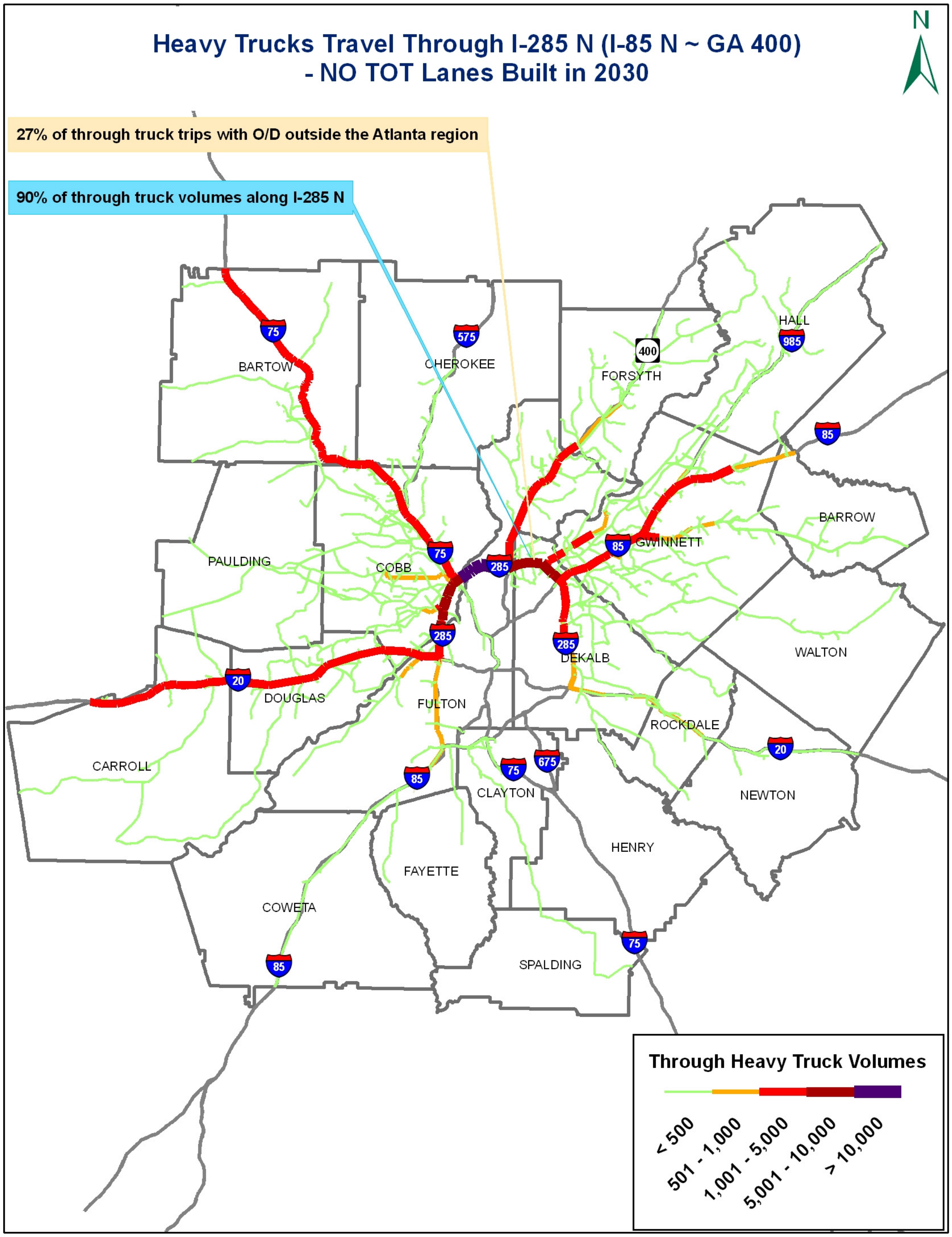


Figure 4-26: Heavy Truck Flows Travel Through I-285 N (I-85 N ~ GA 400)

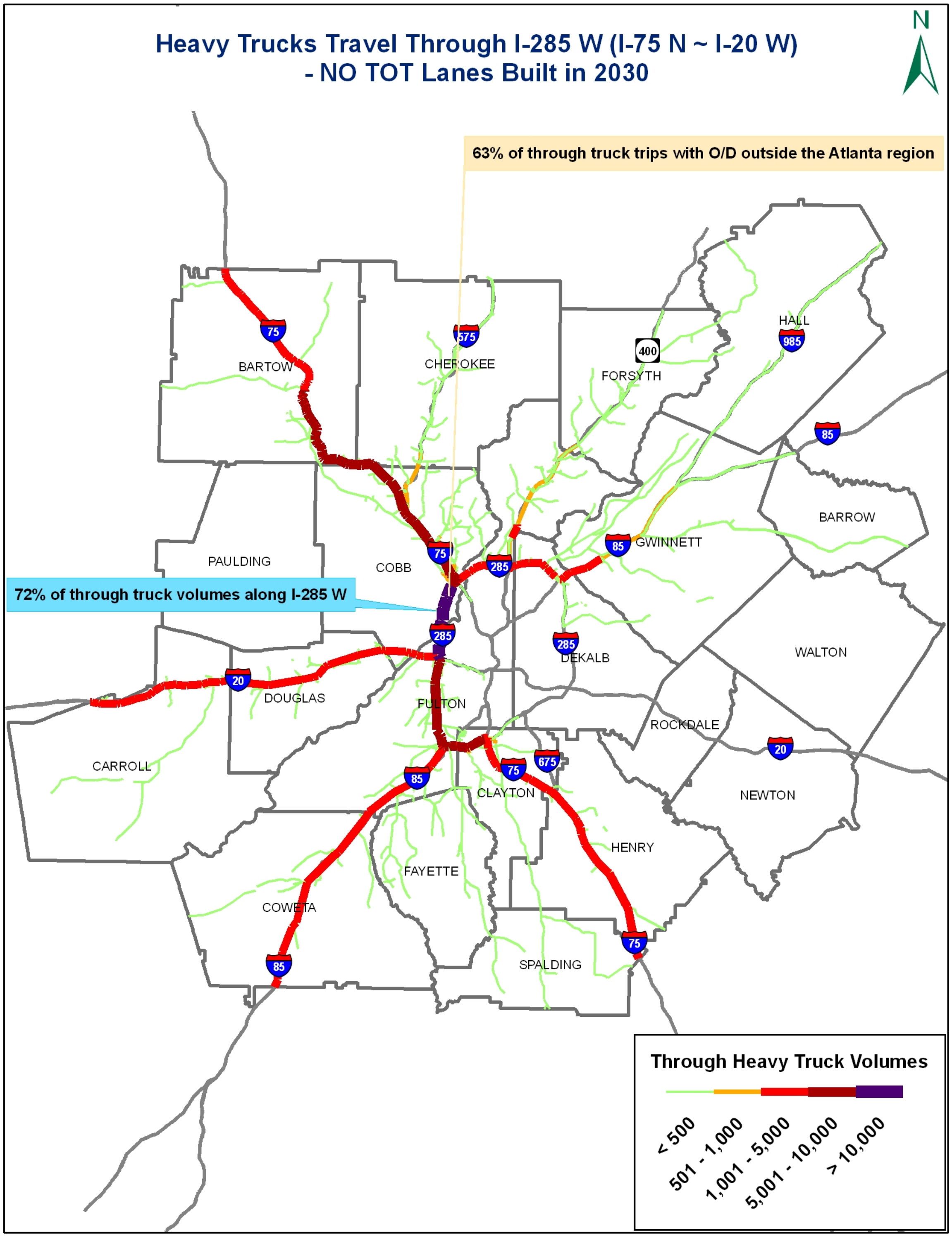


Figure 4-27: Heavy Truck Flows Travel Through I-285 W (I-75 N ~ I-20 W)

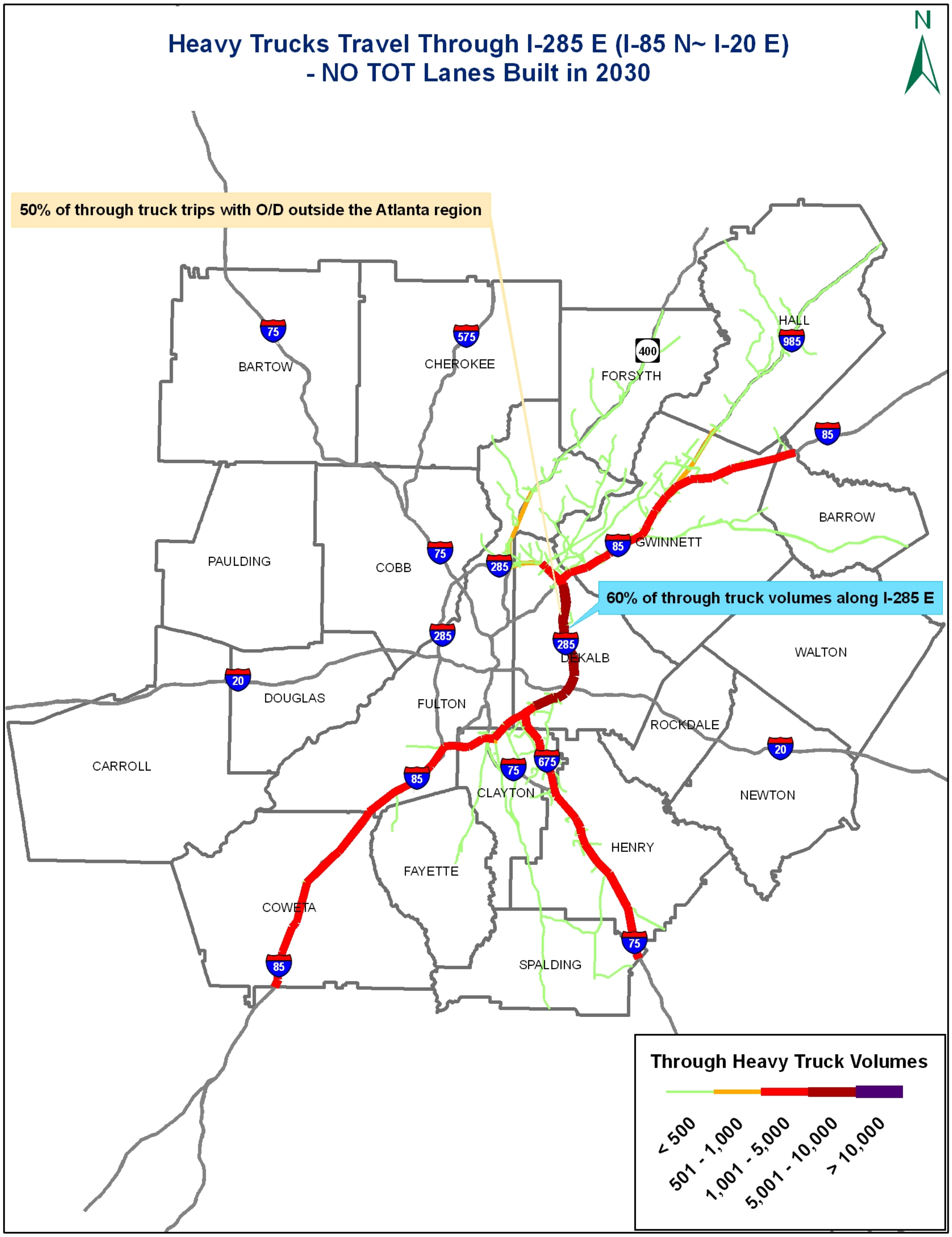


Figure 4-28: Heavy Truck Flows Travel Through I-285 E (I-85 N ~ I-20 E)

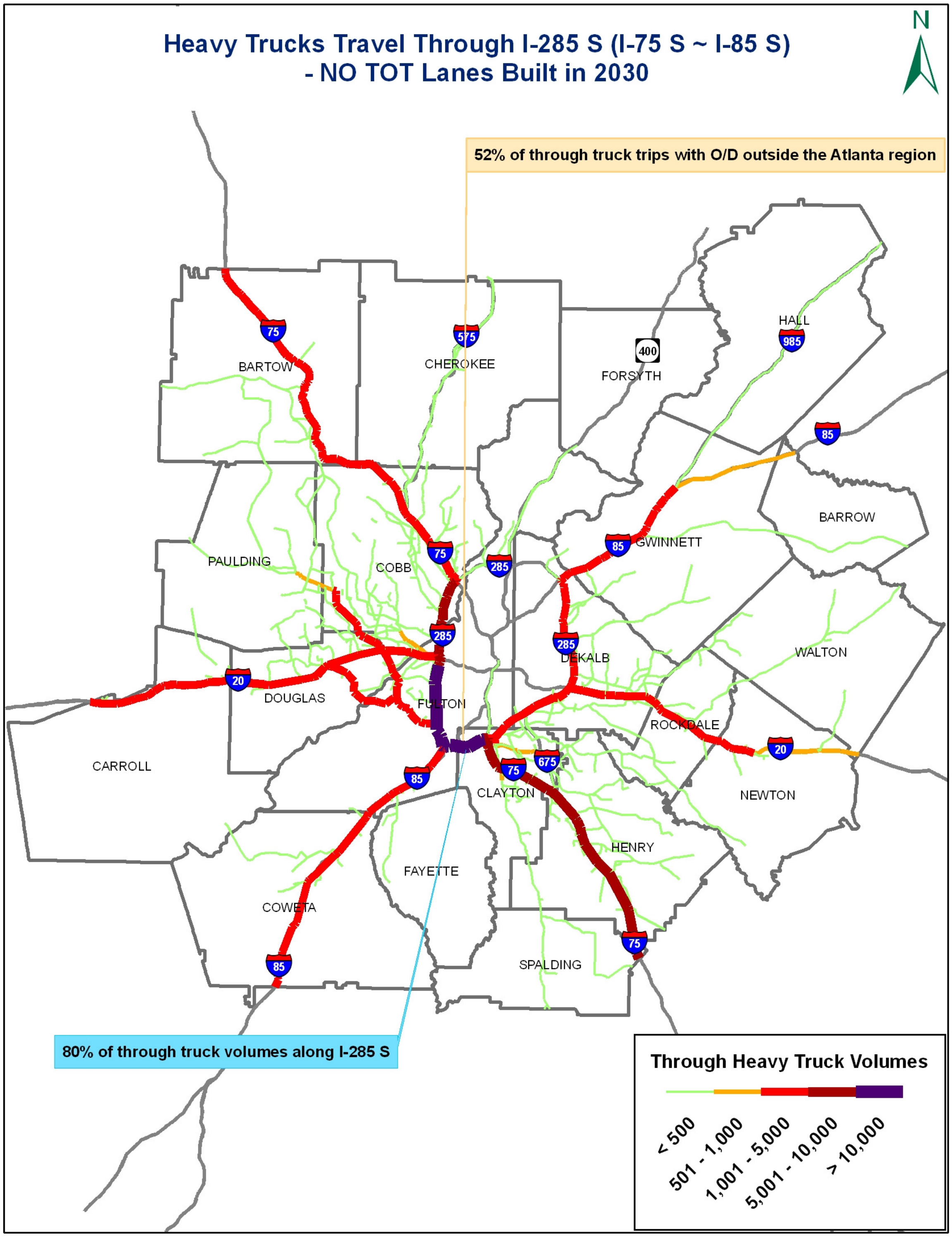


Figure 4-29: Heavy Truck Flows Travel Through I-285 S (I-75 S ~ I-85 S)

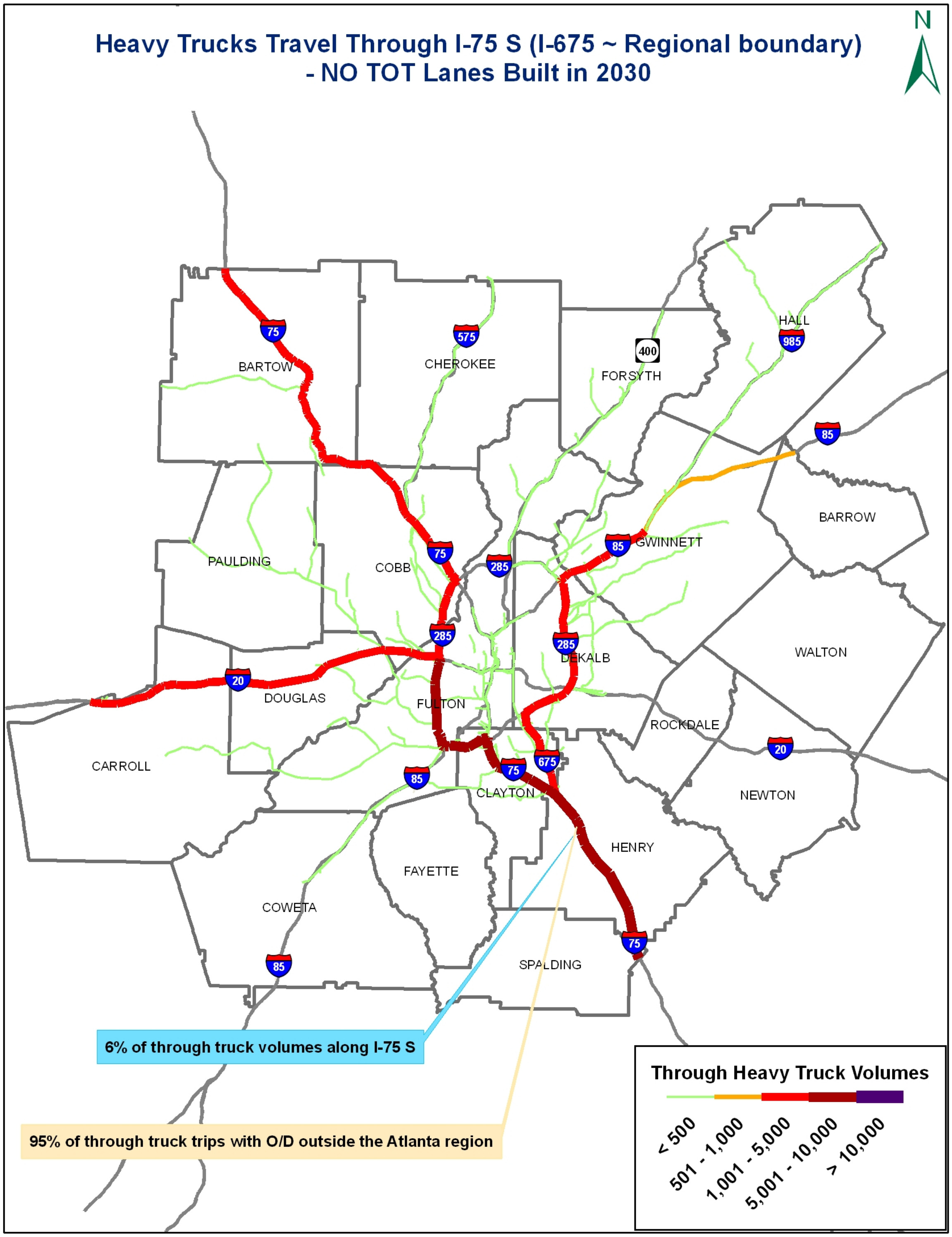


Figure 4-30: Heavy Truck Flows Travel Through I-75 S (I-675 ~ Region Boundary)

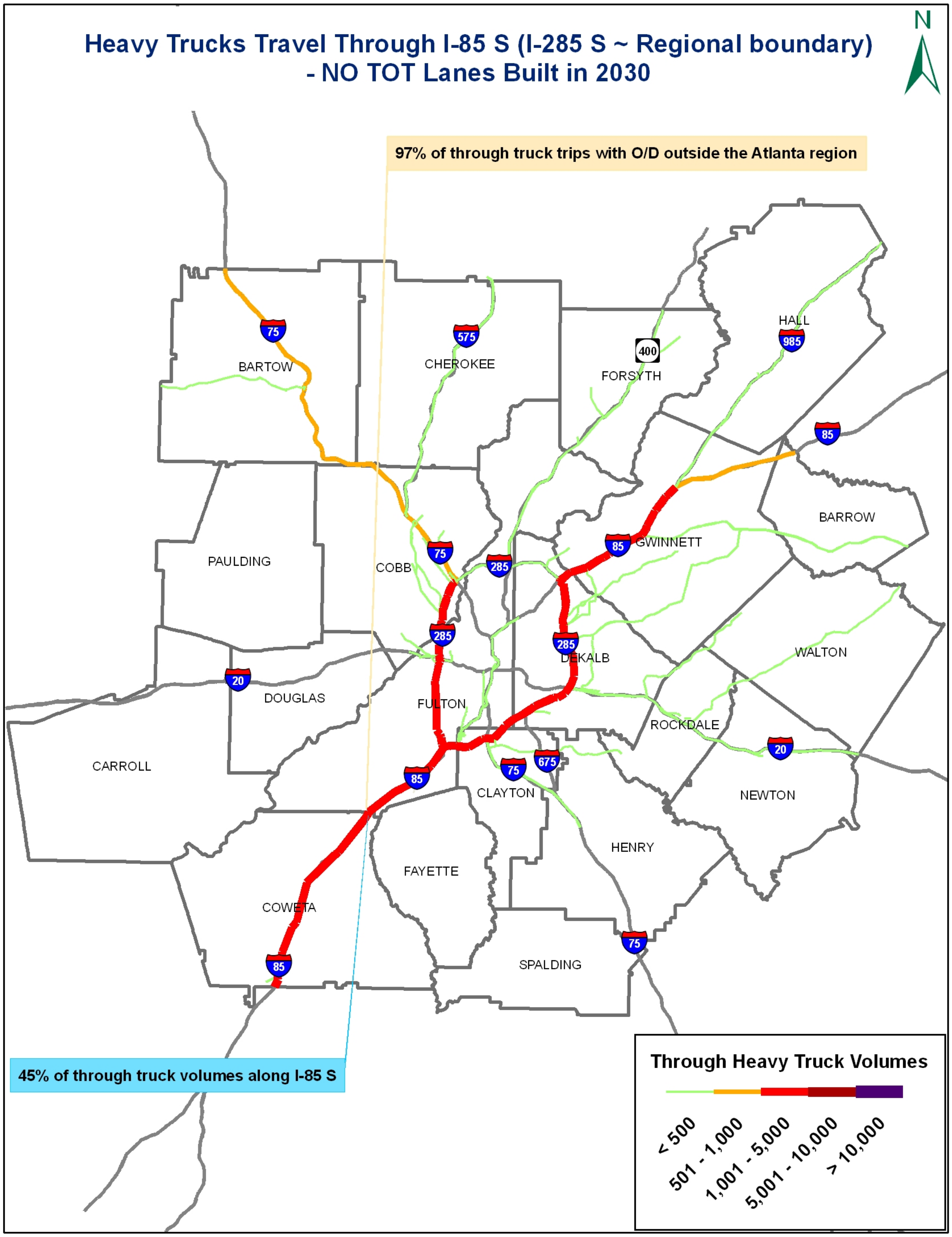


Figure 4-31: Heavy Truck Flows Travel Through I-85 S (I-285 S ~ Region Boundary)

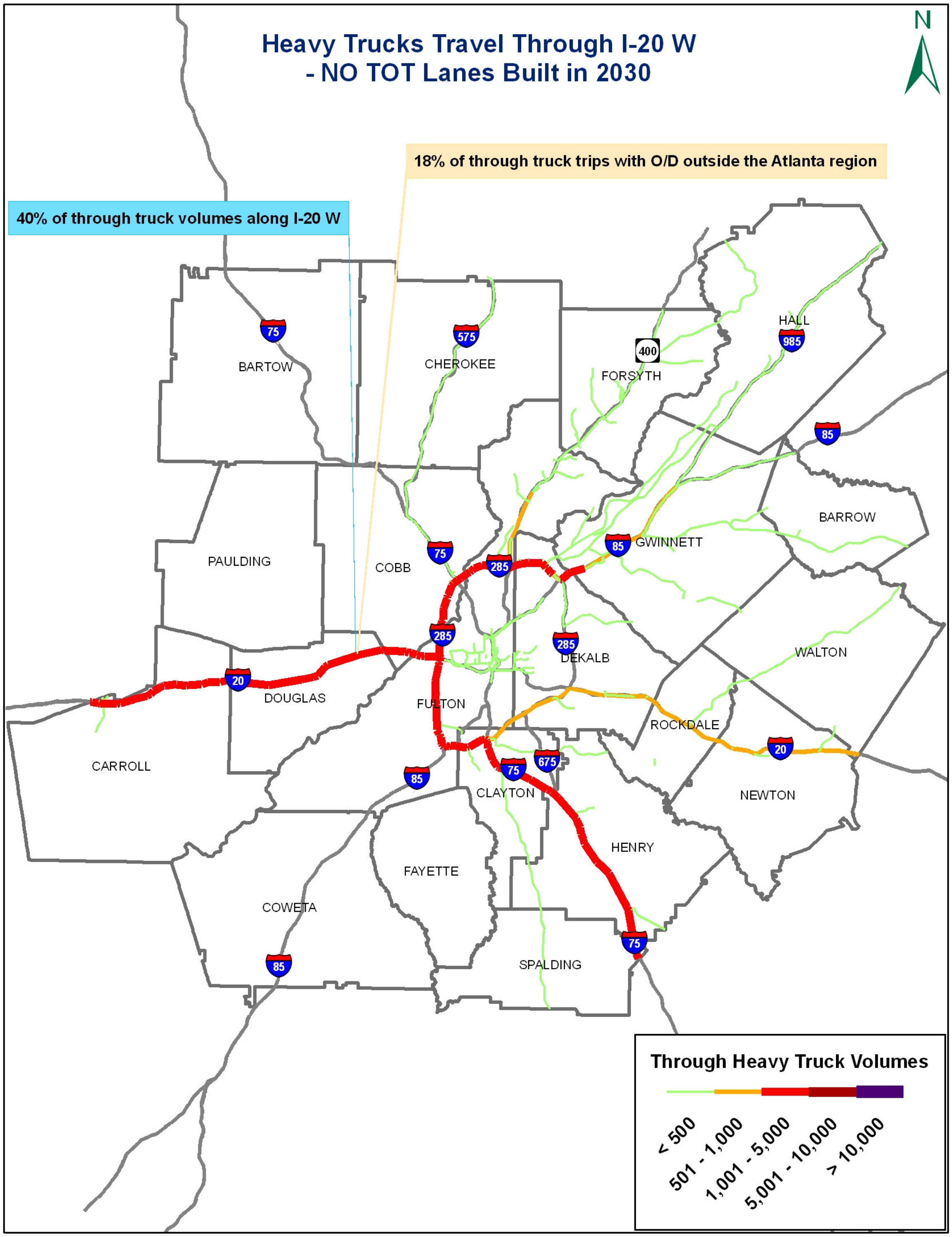


Figure 4-32: Heavy Truck Flows Travel Through I-20 W (I-285W ~ Region Boundary)

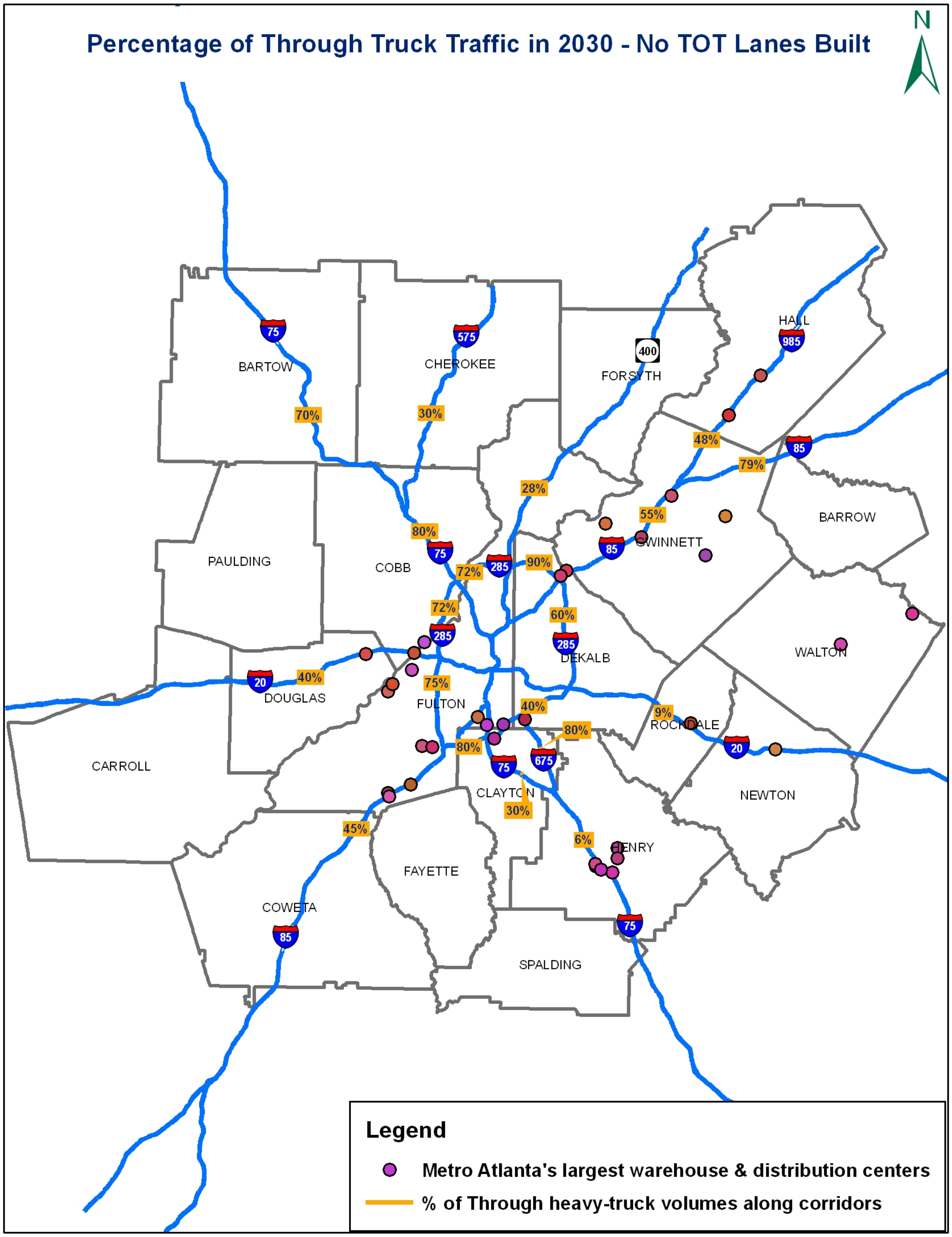


Figure 4-33: Percentage of Through Heavy Truck Traffic on Atlanta Regional Interstates

4.4.2. Relocation of HOV Lanes

The placement of TOT lanes must consider the location of existing HOV lanes. In general, HOV lanes are located in the inside lanes to serve long-distance commute trips. These locations are also most appropriate for through truck trips. Considering the relocation costs and construction effects on HOV lane users, engineers may consider locating TOT lanes between HOV lanes and general purpose lanes. In this design pattern, both HOV lanes and TOT lanes need exclusive access ramps to avoid weaving conflicts.

4.4.3. Acquisition of Right of Way

Engineering designs regarding the placement of TOT lanes, the number of lanes, and the location of exclusive interchanges/ramps are dependent on the available right of way. Additional right of way along an existing corridor should provide the area for adding at least two lanes in each direction and for building access ramps at specific interchanges. Considering safety and operational efficiency, the placement of TOT lanes should be continual and consistent along an entire corridor. If there is sufficient right of way along the corridor, then TOT lanes can be placed in the inside or outside lanes upon the completion of additional lanes. However, if there is no sufficient right of way along the corridor, TOT lanes may be placed in the existing median and exclusive access ramps need be considered in order for trucks to avoid crossing the GP lanes.

4.5. Selection Criteria of Optimum Toll Rates

Truck drivers may select alternative routes if toll rates are too high, which results in low utilization of TOT lanes and more congestion on alternative routes. Similarly, truck drivers may be attracted to using TOT lanes if toll rates are less than perceived benefits, a situation which causes more congestion and lower travel speed on TOT lanes. Various toll rates based on different time periods and travel directions were evaluated to determine the trade-offs between operational efficiency and revenue generation. Derived from the analysis of various toll rates, the optimum toll rates for TOT lanes were determined based on the following four criteria: (1) maximum toll revenues, (2) acceptable level of service, (3) utilization rate > 50%, and (4) truck diversion rate > 0.

4.5.1. Maximum Toll Revenues

To create the potential for self-financing TOT lanes, the selection of optimum toll rates should generate maximum revenues to cover operating and maintenance costs, and some portion of capital costs. Optimum toll rates that generate maximum revenues or slightly lower if they provide better traffic operating conditions were examined in this research.

4.5.2. Acceptable Level of Service

Level of service can be expressed by volume-to-capacity (V/C) ratios or average travel speeds. Referenced from the HCM and GDOT, V/C ratios for LOS C and LOS D less than 0.7 and 0.85, respectively were used (TRB 2000, GDOT 2006). In addition, the HCM defines the average travel speeds on two-lane highways for LOS C and LOS D as at least 45 mph and 40 mph respectively; average travel speeds on multilane highways and freeway segments vary by free-flow speeds (TRB 2000). For example, a basic freeway segment with a free-flow speed of 60 mph under levels of service C and D should have at least average travel speed of 60 mph and 57 mph (at the maximum density of 26 and 35 passenger cars per mile per lane), respectively. TOT lane traffic should be able to maintain a travel speed of at least LOS C or LOS D operating conditions under optimum toll rates. The desirable travel speed on TOT lanes that varies by traffic condition and corridor was examined. For example, a travel speed of LOS C may be achievable on some toll corridors with a lower truck travel demand; however, some toll corridors with an excessive truck travel demand may be able to maintain a travel speed of only LOS D during peak periods.

4.5.3. Utilization Rate

This research defines the utilization rate of TOT lanes as truck volumes on TOT lanes divided by total truck volumes on the interstate (general purpose lanes and TOT lanes), calculated as follows:

$$\text{Utilization rate} = \frac{\text{Truck volume on TOT lanes}}{\text{Total truck volume on Interstate (general purpose lanes + TOT lanes)}}$$

This criterion is used to select an optimum toll rate that can justify transportation investments on TOT lanes and relieve congestion on general purpose lanes. For example, with a total of 1,000 trucks on the interstate, in which 600 trucks use TOT lanes and 400 trucks use general purpose lanes, the utilization rate of TOT lanes is 60%. If the utilization rate is lower than 50%, which means more than half of trucks stay on general purpose lanes, then this toll rate may need to be adjusted lower to optimize economic investments because most trucks would rather use congested general purpose lanes than use TOT lanes.

4.5.4. Truck Diversion Rate

The truck diversion rate measures the change in truck volumes before and after building TOT lanes. The truck diversion rate is defined as:

Truck diversion rate =

$$\frac{\text{Difference of total truck volume on Interstate between after and before building TOT lanes}}{\text{Total truck volume on Interstate before building TOT lanes}}$$

For example, there are 1,000 trucks on the interstate before building TOT lanes. If there were 1,200 trucks on the interstate after building TOT lanes, then the truck diversion rate is 20% because 200 trucks are attracted from local roadways to TOT lanes. If there are only 700 trucks on the interstate after building TOT lanes, then the truck diversion rate is -30% because 300 trucks are unwilling to use TOT lanes and select local roadways instead. This criterion is used to identify whether trucks will divert to free local roadways to avoid high toll rates and thereby cause local traffic congestion or increase accidents.

This analysis assumes a fixed trip table, that is, no new truck trips are generated due to excess capacity.

4.6. Appraisal Scheme of Feasible TOT Lane Systems

Feasible TOT lane systems in the Atlanta region were identified based on the analysis of operating performance. Performance measures included level of service on general purpose lanes and TOT lanes, travel speed on general purpose lanes and TOT lanes, delay on general purpose lanes and TOT lanes, travel time savings by using TOT lanes, truck vehicle-miles traveled (VMT) on general purpose lanes before and after the building of the TOT lanes (as a measure of reduction in truck-car crashes and air pollution), and toll revenue generation. Different scenarios are proposed in the appraisal scheme including whether to add general purpose lanes or new TOT lanes and whether to use mandatory or voluntary TOT lanes.

4.6.1. Modeling Scenarios of TOT Lanes

In order to identify feasible TOT lane corridors, various combinations of candidate TOT lanes in the Atlanta region were identified based on the analysis of through truck traffic flows as discussed in 4.4.1. Table 4-6 and Figure 4-34 show the feasible TOT lane candidates. The feasible TOT lane candidates are determined based on performance measures discussed in Chapter 5.

Table 4-6: Feasible TOT Lane Candidates in the Atlanta Region

#	Individual TOT Lane Corridors
1	I-75 N (from I-285 N to SR 20 in Bartow county)
2	I-85 N (from I-285 N to I-85@I-985 in Gwinnett county)
3	I-285 Perimeter (I-285 N, I-285 W, I-285 S, and I-285 E)
4	I-20 E (from I-285 E to SR 138 in Rockdale county)
5	I-20 W (from I-285 W to Atlanta regional boundary in Carroll county)
6	I-85 S (from I-285 S to SR 34 in Coweta county)
7	I-75 S (from I-285 S to Atlanta regional boundary in Spalding county)
#	**Combination of TOT Lane Corridors**
1	I-75 N + I-285 W + I-285 S + I-75 S
2	I-75 N + I-285 W + I-285 S + I-75 S + I-85 S
3	I-75 N + I-285 W + I-285 S + I-75 S + I-85 S +I-20 W
4	I-75 N + I-285 W + I-285 S + I-75 S + I-85 S +I-20 W + I-285 N + I-85 N
5	I-75 N + I-285 W + I-285 S + I-75 S + I-85 S +I-20 W + I-285 N + I-85 N + I-285 E
6	I-75 N + I-285 W + I-285 S + I-75 S + I-85 S +I-20 W + I-85 N + I-285 E + I-20 E
7	I-75 N + I-285 W + I-285 S + I-75 S + I-85 S + I-285 N + I-85 N + I-285 E
8	I-75 N + I-285 W + I-285 S + I-75 S + I-85 S +I-20 W + I-285 N + I-85 N + I-285 E + I-20 E

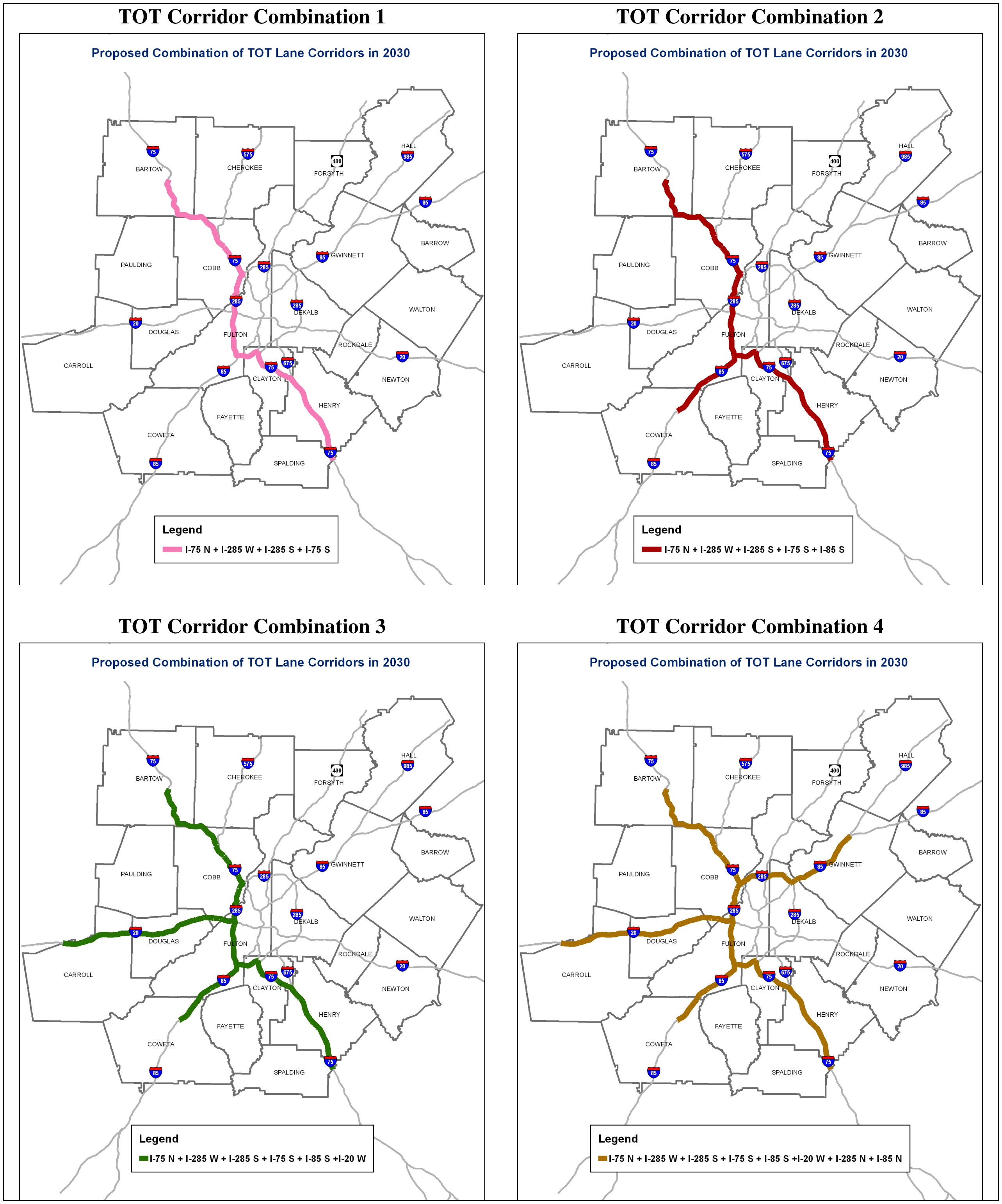
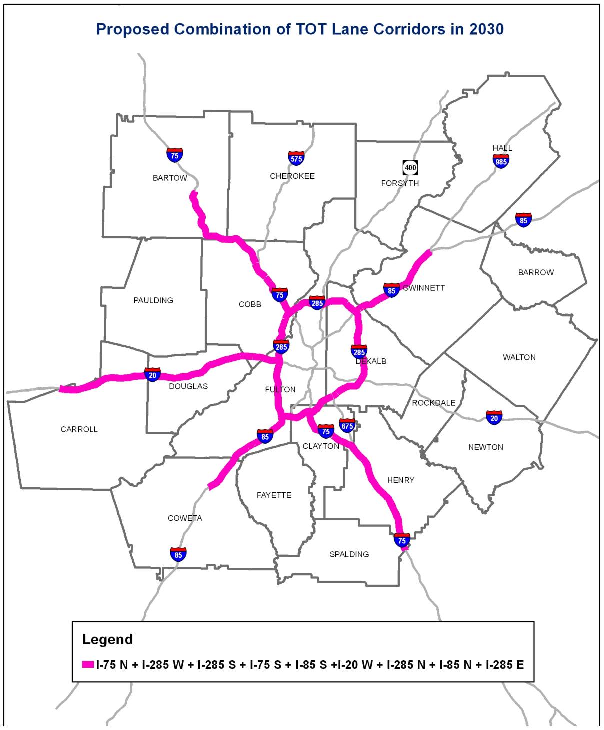
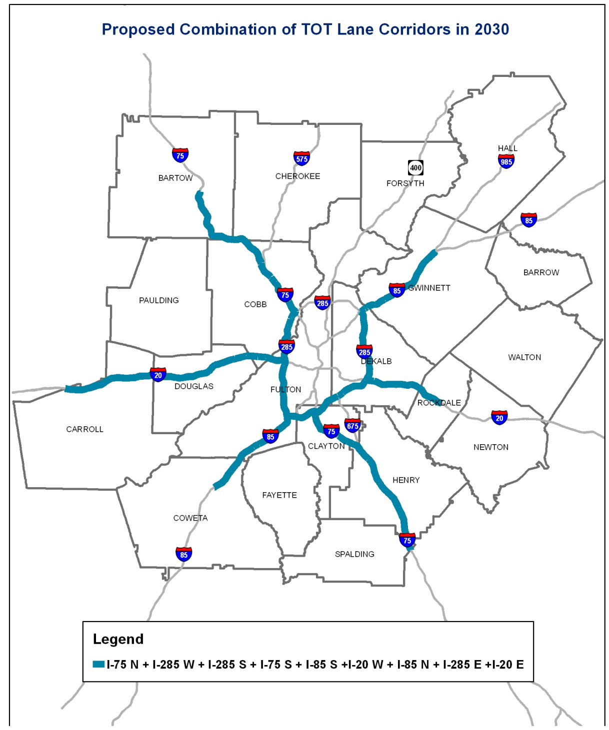


Figure 4-34: Combinations of Potential TOT Corridors in the Atlanta Region

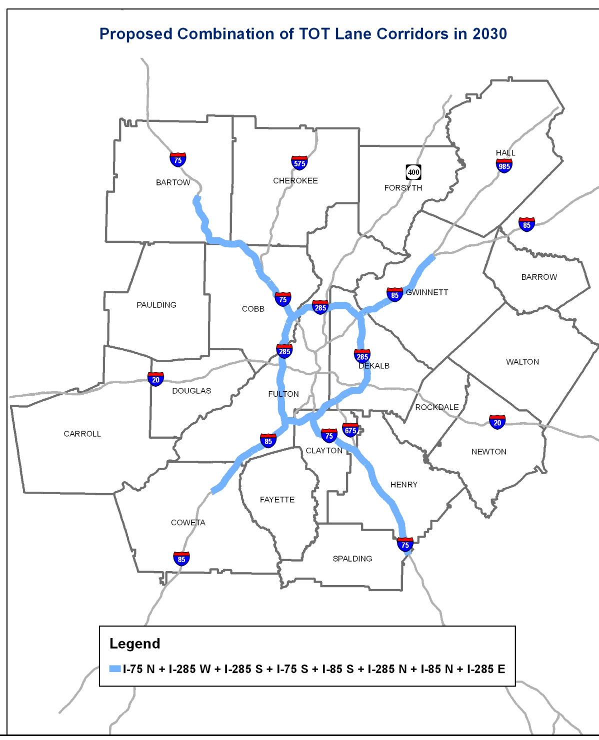
TOT Corridor Combination 5



TOT Corridor Combination 6



TOT Corridor Combination 7



TOT Corridor Combination 8

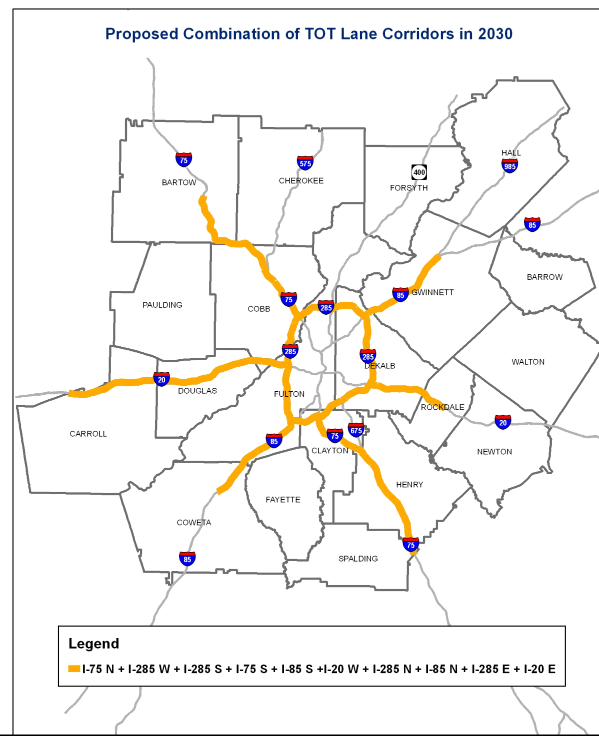


Figure 4-34 (cont.): Combinations of Potential TOT Corridors in the Atlanta Region

4.6.1.1. Add GP Lanes or Build TOT Lanes

Compared to building TOT lanes, adding general purpose (GP) lanes is easier and cheaper. This research compared the modeling results of building two TOT lanes or two general purpose lanes in each direction. The comparison results of these performance measures are discussed in Chapter 5.

4.6.1.2. Mandatory or Voluntary TOT Lanes

Most state law requires heavy trucks to travel on the outside lane on interstate highways. However, there is no legislation limiting medium trucks to outside lanes. The recommendation to allow medium trucks on TOT lanes is based on three considerations: (1) the growth rate of medium trucks has continued to increase. For example, medium truck volumes are currently about one third of heavy truck volumes on I-75 NW, and the number of medium trucks will grow to approximately half the number of heavy trucks by 2030; (2) passenger car drivers always want as few trucks as possible to use general purpose lanes, whether they are medium trucks or heavy trucks; and (3) medium trucks using TOT lanes can increase the generation of toll revenues and the utilization of TOT lanes. Therefore, this research analyzes two truck toll policies: (1) voluntary TOT lanes for heavy trucks and medium trucks and (2) mandatory TOT lanes for through heavy trucks and voluntary TOT lanes for medium trucks. The modeling results are discussed in Chapter 5.

4.6.2. Sensitivity Analysis of Various Values of Time

The higher a trucker's value of time, the higher is a trucker's willingness to pay tolls to use TOT lanes during traffic congestion period. Truckers' willingness-to-pay may vary by state. For example, the average truckers' value of time is higher in California ($73/hr) than in Georgia ($31/hr), as shown in Table 4-7.

To provide traffic engineers with a better understanding of trade-offs between toll revenues and traffic operating conditions and make this approach more applicable to other states, this research conducted sensitivity tests of different levels of truckers' value of time by using a factor of 0.8, 1.5, 2.0, and 2.5 applied to the value of time in Georgia. Modified willingness-to-pay distribution curves reflect a range of a lower value of time of \$25 per hour (\$31×0.8) to a higher value of time of \$47 (\$31×0.8), \$62 (\$31×2.0), and \$78 (\$31×2.5) per hour, as shown in Figure 4-35.

Based on the sensitivity analysis of various truckers' values of time, the relationships among toll rates and performance measures such as revenue generation, congestion indexes (LOS, travel speed, delay, and travel time savings), TOT lane utilization rates, and truck diversion rates were graphically identified. For example, anticipated results should illustrate that with increased value of time comes increased revenues and better travel conditions under optimum toll rates (filled symbols). Figure 4-36 shows an example of the anticipated graphical analysis.

Table 4-7: Examples of Trucker's Average Value-of-Time

	Value-of-Time ($/Hr)		Shipper / Carrier	Survey Year	Survey Method	Survey Interstate Corridor
	Average	Range				
California[1]	52	22 ~ 193	Heavy truck	1999	SP	
USA[2]	25 (national average)		Heavy truck	2000		
Minnesota[3]	50	0 ~ 80	Heavy truck	2003	SP	
26 States[4]		25 ~ 200	Shipper / Driver	2005		I-5, I-10, I-45, I-65, I-70
SCAG[5]	73		Heavy truck	2005		I-10, I-15
Virginia[6]	60		Heavy truck	2006		I-81
Georgia[7]	22 / 31	0 ~ 240	Shipper / Driver	2006	SP	I-75

Notes:
[1]: NCHRP Report 431, 1999.
[2]: Caltrans, 2004.
[3]: Levinson and Smalkoski, 2003.
[4]: FHWA, 2005.
[5]: SCAG, 2005.
[6]: Virginia DOT, 2006.
[7]: Georgia SRTA, 2006.

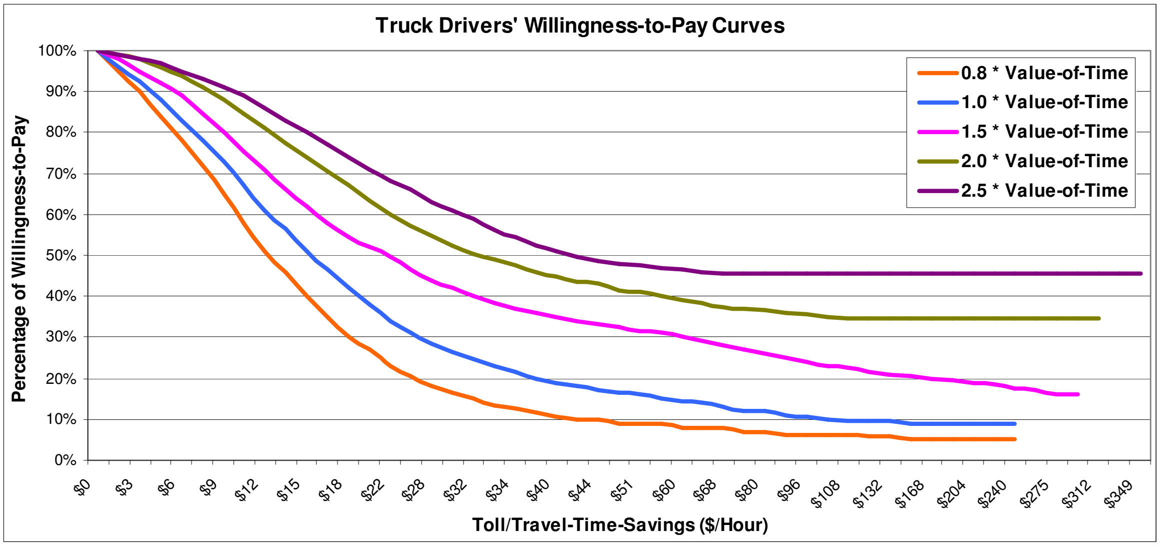


Figure 4-35: Truckers' Willingness-to-Pay Curves by Factoring VOT with 0.8, 1.5, 2.0, and 2.5

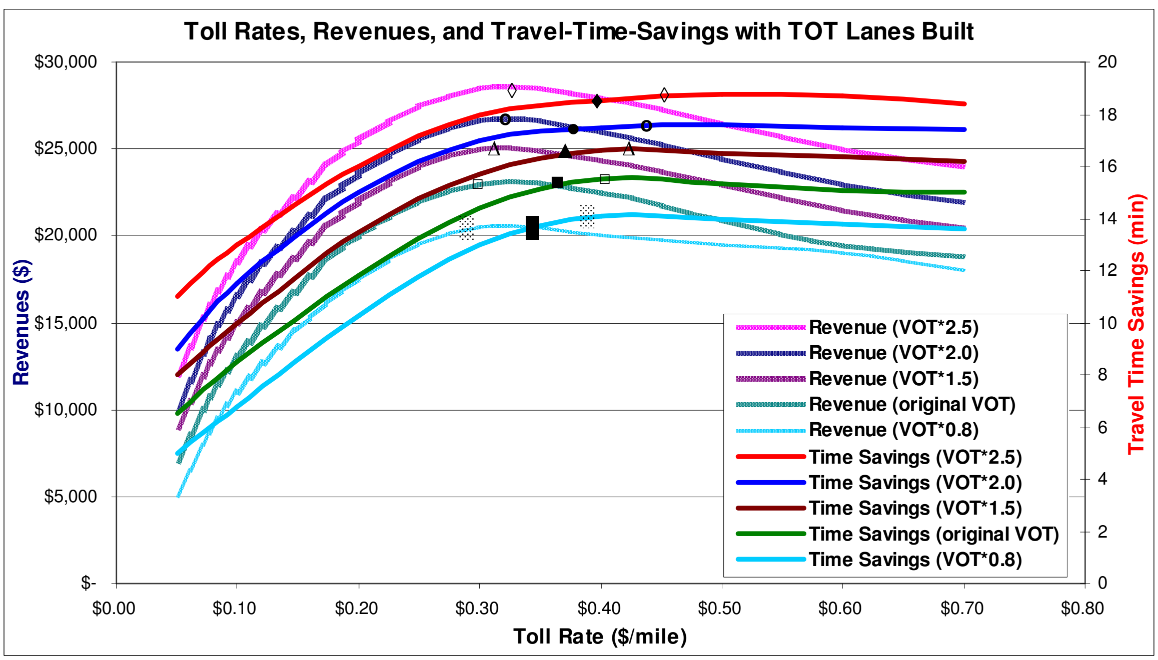


Figure 4-36: Anticipated Graphical Analysis of Toll Rates, Revenues, and Travel-Time-Savings

4.7. Summary

This chapter discussed the methodology utilized to identify feasible TOT lane candidates in the Atlanta interstate system. This research used FHWA's criteria to validate the ARC travel demand model. The validation results of differences between model highway link volumes and GDOT observed traffic counts show acceptable errors and meet FHWA's desirable targets except in the cases of two interstate segments under interchange reconstruction.

A screening approach to identify TOT lane candidates in the projected year 2030 was developed by utilizing the validated travel demand model. The recommended screening criteria derived from the Atlanta regional interstate system included: (1) level of service during the PM peak period worse than E or F, (2) daily truck volumes including medium and heavy trucks greater than 9,000 trucks AADT, (3) daily truck percentage including medium and heavy trucks greater than 14%, (4) high truck-related crash rates per 100 million vehicle-miles traveled over regional average crash rates, and (5) at least 90th percentile truckers' cost saving threshold less than the monetary value of travel time savings gained from using TOT lanes. The feasible boundary/extent on TOT lane corridors is determined by applying all the screening criteria simultaneously. Furthermore, different levels of truckers' cost saving threshold including 50th, 60th, 70th, and 80th percentile are tested and compared with the 90th percentile criterion. Because the results show there is significant difference among the five percentages in the selection of TOT lane candidates, the 90th percentile criterion is selected because it includes the largest number of highway links as potential TOT lanes.

Through truck traffic along each corridor is identified by a select link analysis approach and is used to evaluate the placement of a TOT lane whether in the inside or outside lane. Based on the results of through truck traffic from the entire regional interstates, this research recommends a threshold value for inside TOT lanes of more than

50% through truck volumes with direct access to major freight generators. Outside TOT lanes are appropriate for less than 30% through truck volumes.

This research determines an optimum toll rate to implement the pricing strategy on TOT lanes based on (1) maximum revenue generation, (2) an acceptable level of service of at least C or D, (3) a utilization rate of TOT lanes greater than 50%, and (4) a truck diversion rate from local roads to TOT lanes greater than 0%. Furthermore, modeling scenarios of constructing general purpose lanes or TOT lanes and implementing mandatory or voluntary use of TOT lanes are proposed to evaluate the operational performance of different scenarios. Finally, this research analyzes different truckers' values of time to reflect the application of the TOT pricing strategy to other geographic areas.

CHAPTER 5

RESEARCH RESULTS

Two examples of the analysis of TOT lanes for different geographic scale have been examined in this research: an individual corridor (I-285 west) and the Atlanta regional interstate system. The performance of different scenarios of building two general purpose (GP) lanes or two TOT lanes (voluntary and mandatory use) in each direction were compared. In addition, the screening approach developing in this research was applied to identify statewide TOT lane candidates in Georgia. This chapter presents the results of these analyses.

5.1. Feasible TOT Lanes in Corridors

Of the individual TOT corridors identified by the screening criteria, I-285 west was selected as an example to examine the implementation of inside TOT lanes. According to Georgia policy, no through heavy truck trips are allowed to travel inside I-285 including the I-75/I-85 connector and I-20, except trucks that are permitted. I-285 has thus become a major truck bypass of central Atlanta. The analysis of through truck trips indicates that 72% of the truck trips traveling along I-285W1 (from I-75N to I-20W) and 75% along I-285W2 (from I-20W to I-85S) are trips that pass through that section. Table 5-1 illustrates traffic operational conditions during the 2030 PM peak period resulting from the ARC travel demand model. As shown, I-285 west will experience significant delays and severe congestion of levels of service E and even F on the GP lanes.

Either implementing voluntary TOT lanes or mandatory TOT lanes on I-285 west will result in increased travel speed, decreased travel time, reduced delay, and reduced truck vehicle miles traveled on GP lanes, as shown in Table 5-2 and Table 5-3. As expected, mandatory TOT lanes demonstrate better performance on the GP lanes than do the voluntary TOT lanes because all through heavy trucks are forced to travel in the TOT lanes. However, voluntary TOT lanes show better performance (higher travel speed and less delay) on TOT lanes than do mandatory TOT lanes because through heavy trucks have an option to use TOT lanes or GP lanes based on their willingness to pay a toll cost. Therefore, there will not likely be of many trucks in the TOT lanes for the voluntary TOT lane scenario. Additionally, the lower volume-to-capacity ratios on the voluntary TOT lanes indicate that excess capacity exists and thus the freeway is not being optimally managed. Even with TOT lanes, traffic conditions on the GP lanes and HOV lanes still show poor levels of service. The potential need for converting HOV lanes into high occupancy toll (HOT) lanes may have to be considered to shift those single occupancy vehicles willing to pay from GP lanes to HOT lanes.

With respect to adding two GP lanes in each direction instead of two TOT lanes, the performance measures for GP lanes show that adding GP lanes is better than building voluntary TOT and mandatory TOT lanes, as shown in Table 5-4. However, adding GP lanes will attract more local truck traffic from alternative routes to the freeway GP lanes (resulting in increased vehicle miles traveled). In terms of TOT lanes, both voluntary and mandatory TOT lanes show significant travel time savings for trucks traveling on the TOT lanes and presumably a reduced risk of truck-related crashes as compared with traveling on GP lanes.

Figure 5-1 and Figure 5-2 show the relationship between utilization rate, revenue and respective toll levels based on voluntary TOT lanes on I-285W1 and I-285W2, respectively. These figures show a desired utilization rate target of 50% in the voluntary TOT lanes in order to reduce congestion on the general purpose lanes. Once toll rates rise above the optimum toll rate, even though revenues still increase because of a small percentage (approximately 9%) of trucks with very high willingness-to-pay reaching more than $200/hour, the utilization rate in the peak direction decreases to less than 50% because most trucks are unwilling to pay such high toll costs. Once the utilization rate is lower than 50%, TOT facilities are not optimally used and GP lanes do not see much improvement. Additionally, the results demonstrate that voluntary TOT lanes can provide trucks with higher travel time savings, but mandatory TOT lanes can generate higher toll revenues.

Figure 5-3 and Figure 5-4 show off-peak revenues during midday and night periods. Traffic conditions on TOT lanes in off-peak hours are not congested and even provide free-flow travel speed in certain time periods. Optimum toll rates for midday are approximately \$0.05/mile ~ \$0.08/mile based on at least a 50% utilization rate and a 0% diversion rate. The directional split of truck traffic between different travel directions in midday and nighttime is insignificant. However, the night period shows very low toll rates of \$0/mile ~ \$0.02/mile because there are no travel time saving benefits in using TOT lanes.

Table 5-1: No-Build Performance Measures of I-285W during 2030 PM Peak Period (3:00 – 7:00 PM)

Corridor	Speed (mph)	Travel Time (min)	Delay (min)	V/C ratio	Vehicle Miles Traveled	Level of Service
I-285 W1_GP_NB	33	22.67	12.49	0.90	43,506	E
I-285 W1_GP_SB	25	34.11	23.18	1.02	41,743	F
I-285 W1_HOV_NB	45	14.86	4.84	0.73		D
I-285 W1_HOV_SB	36	20.25	10.39	0.86		E
I-285 W2_GP_NB	29	23.64	12.99	0.95	50,767	E
I-285 W2_GP_SB	26	26.07	15.43	0.99	49,444	E

Note: Vehicle miles traveled include both heavy trucks and medium trucks only.

Table 5-2: Voluntary TOT Performance Measures of I-285W during 2030 PM Peak (3:00 – 7:00 PM)

Corridor	Speed (mph)	Travel Time (min)	Delay (min)	V/C ratio	Vehicle Miles Traveled	Revenues ($) / Toll ($/mile)	Utilization rate	Diversion rate
I-285 W1_GP_NB	36	19.72	9.55	0.85	24,741			
I-285 W1_GP_SB	29	27.99	17.06	0.96	23,629			
I-285 W1_TOT_NB	58	10.69	0.35	0.30	23,807	$5,750 / $0.25	50%	12%
I-285 W1_TOT_SB	58	10.67	0.31	0.29	23,046	$9,220 / $0.40	50%	16%
I-285 W1_HOV_NB	46	14.3	4.28	0.71				
I-285 W1_HOV_SB	38	18.97	9.11	0.85				
I-285 W2_GP_NB	34	19.64	8.99	0.89	25,935			
I-285 W2_GP_SB	30	22.04	11.40	0.94	26,830			
I-285 W2_TOT_NB	59	11.37	0.35	0.30	25,783	$5,160 / $0.20	50%	2%
I-285 W2_TOT_SB	59	11.36	0.33	0.29	25,026	$7,500 / $0.30	50%	5%

Note: Performance measures are derived from optimum toll rates and based on toll policy of voluntary heavy trucks and voluntary medium trucks.
Travel time savings are trucks travel time on GP lanes minus trucks travel time on TOT lanes; Delay is travel time under congested travel speed minus travel time under free-flow speed; Vehicle miles traveled include both heavy trucks and medium trucks.

Table 5-3: Mandatory TOT Performance Measures of I-285W during 2030 PM Peak (3:00 – 7:00 PM)

Corridor	Speed (mph)	Travel Time (min)	Delay (min)	V/C ratio	Vehicle Miles Traveled	Revenues ($) / Toll ($/mile)	Utilization rate	Diversion rate
I-285 W1_GP_NB	37	18.60	8.43	0.83	16,065			
I-285 W1_GP_SB	29	27.51	16.58	0.96	15,322			
I-285 W1_TOT_NB	55	11.48	1.14	0.52	39,055	$9,695 / $0.25	71%	27%
I-285 W1_TOT_SB	55	11.37	1.01	0.49	37,132	$14,853 /$0.40	71%	30%
I-285 W1_HOV_NB	47	14.22	4.19	0.71				
I-285 W1_HOV_SB	38	18.67	8.81	0.84				
I-285 W2_GP_NB	36	18.67	8.03	0.88	15,434			
I-285 W2_GP_SB	32	20.64	10.00	0.92	14,677			
I-285 W2_TOT_NB	55	12.18	1.15	0.51	41,525	$8,305 / $0.20	73%	12%
I-285 W2_TOT_SB	54	12.41	1.38	0.55	44,630	$13,390 /$0.30	75%	20%

Note: Performance measures are derived from optimum toll rates and based on toll policy of mandatory heavy trucks and voluntary medium trucks.
Travel time savings are trucks travel time on GP lanes minus trucks travel time on TOT lanes; Delay is travel time under congested travel speed minus travel time under free-flow speed; Vehicle miles traveled include both heavy trucks and medium trucks.

Table 5-4: Adding GP Lane Performance Measures of I-285W during 2030 PM Peak (3:00 – 7:00 PM)

Corridor	Speed (mph)	Travel Time (min)	Delay (min)	V/C ratio	Vehicle Miles Traveled	Level of Service
I-285 W1_GP_NB	35	18.61	8.43	0.79	49,553	D
I-285 W1_GP_SB	45	14.71	3.78	0.62	57,117	C
I-285 W1_HOV_NB	45	13.73	3.71	0.63		C
I-285 W1_HOV_SB	56	10.58	0.72	0.32		B
I-285 W2_GP_NB	38	16.93	6.28	0.73	62,313	D
I-285 W2_GP_SB	43	15.07	4.43	0.66	65,338	C

Note: Vehicle miles traveled include both heavy trucks and medium trucks.

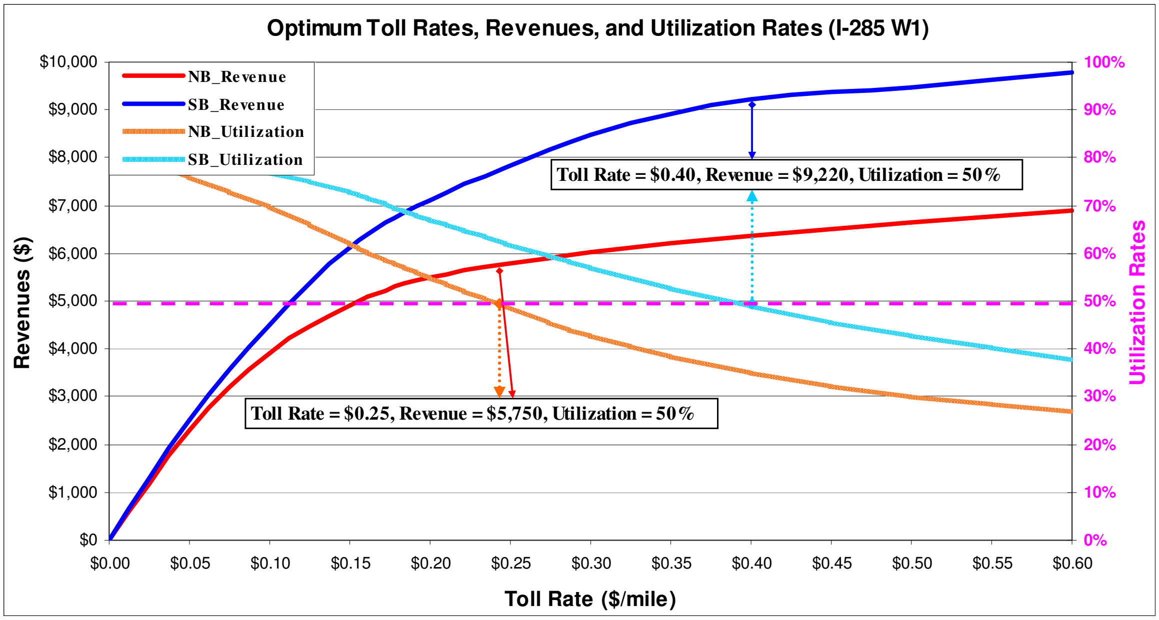


Figure 5-1: Optimum Toll Rates, Revenues, and Utilization on I-285W1 during 2030 PM Peak (Voluntary TOT Lanes)

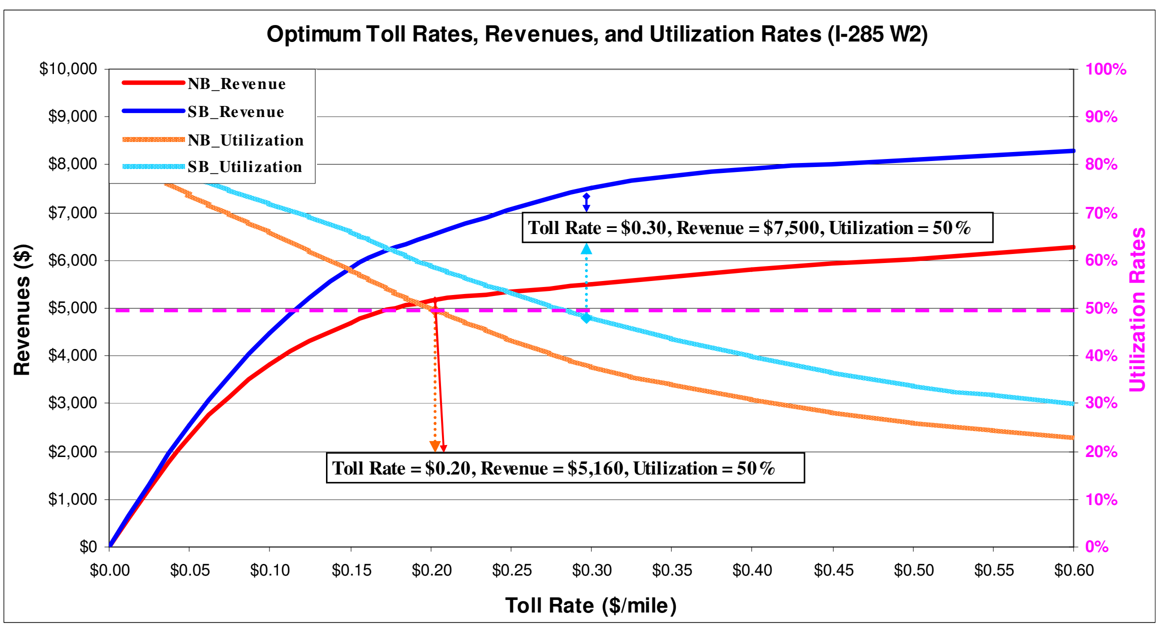


Figure 5-2: Optimum Toll Rates, Revenues, and Utilization on I-285W2 during 2030 PM Peak (Voluntary TOT Lanes)

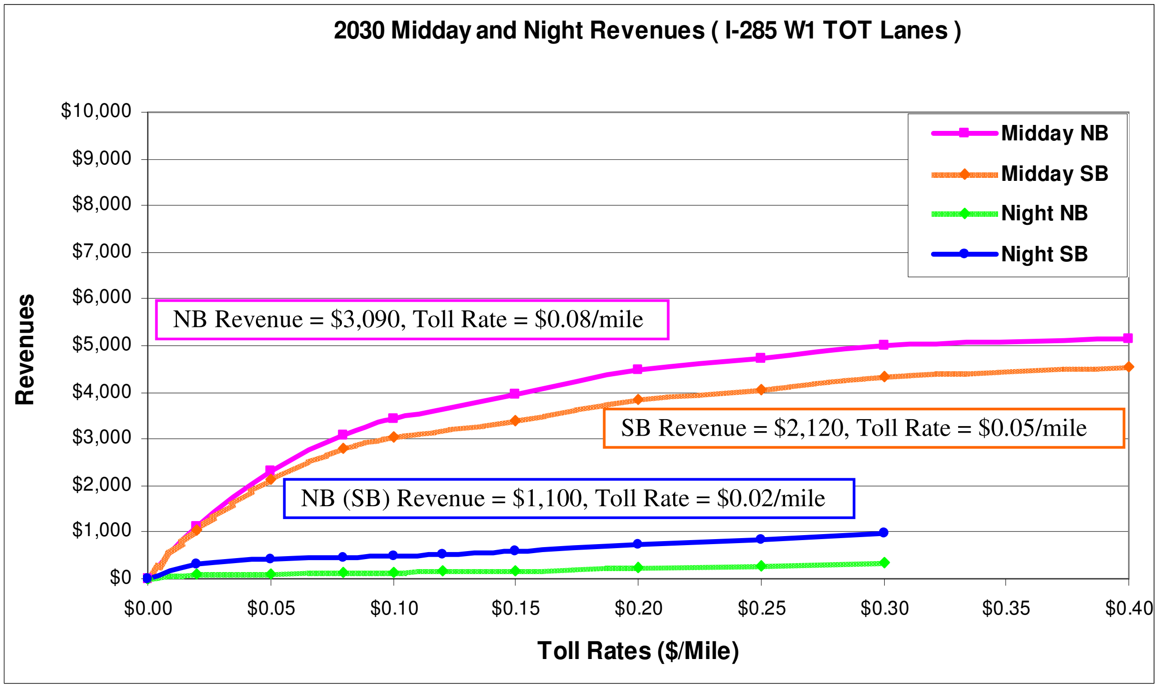


Figure 5-3: Optimum Toll Rates and Revenues on I-285W1 during 2030 Off-Peak (Voluntary TOT Lanes)

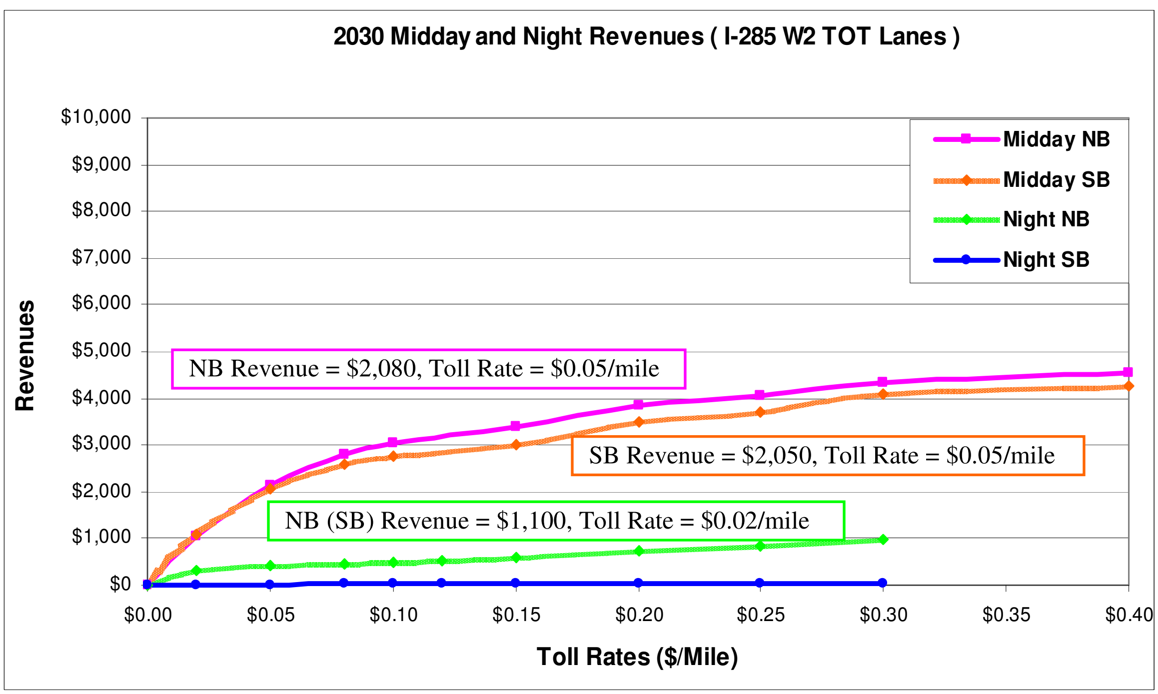


Figure 5-4: Optimum Toll Rates and Revenues on I-285W2 during 2030 Off-Peak (Voluntary TOT Lanes)

The benefits of building TOT lanes in the I-285 corridor can be summarized as (1) trucks experience reduced travel time and delays because TOT lanes provide a better level of service A or B than level of service E or F on the GP lanes during the peak period, thus increasing trip reliability and freight productivity; (2) trucks can operate more efficiently at a travel speed of 20 mph higher than on the GP lanes during the peak period and thus contribute to reduced fuel consumption; (3) truck-car crashes can be reduced because trucks and cars are separated by a barrier; and (4) revenues generated from tolls can be used to finance the project.

This research also analyzed various truckers' values of time including 0.8, 1.5, 2.0, and 2.5 times that of Georgia truckers' to examine the resulting performance of TOT lanes. Figure 5-5 and Figure 5-6 illustrate the examples of I-285W1 in each direction based on voluntary TOT lanes. As expected, the results indicate that higher truckers' values of time generate higher revenues resulting from a willingness to pay a higher toll cost. Toll revenues for the I-285W corridor based on optimum toll rates generated from assuming 0.8, 1.5, 2.0, and 2.5 times that of Georgia truckers' value of time are approximately 0.8, 1.5, 2.5, and 4.0 times the base revenues that would have been collected using Georgia truckers' value of time. Optimum toll rates during the PM peak period derived from 0.8, 1.5, 2.0, and 2.5 times Georgia truckers' value of time (optimum toll rates \$0.20/mile ~ \$0.40/mile) are approximately \$0.15/mile ~ \$0.30/mile, \$0.30/mile ~ \$0.60/mile, \$0.50/mile ~ \$1.00/mile, and \$0.80/mile ~ \$1.50/mile, respectively. In terms of performance measures based on optimum toll rates, higher truckers' values of time produce less travel time savings and slightly lower levels of service on TOT lanes than lower truckers' values of time because a larger number of truckers are willing to use TOT lanes; however, they do result in a higher utilization rate of TOT lanes.

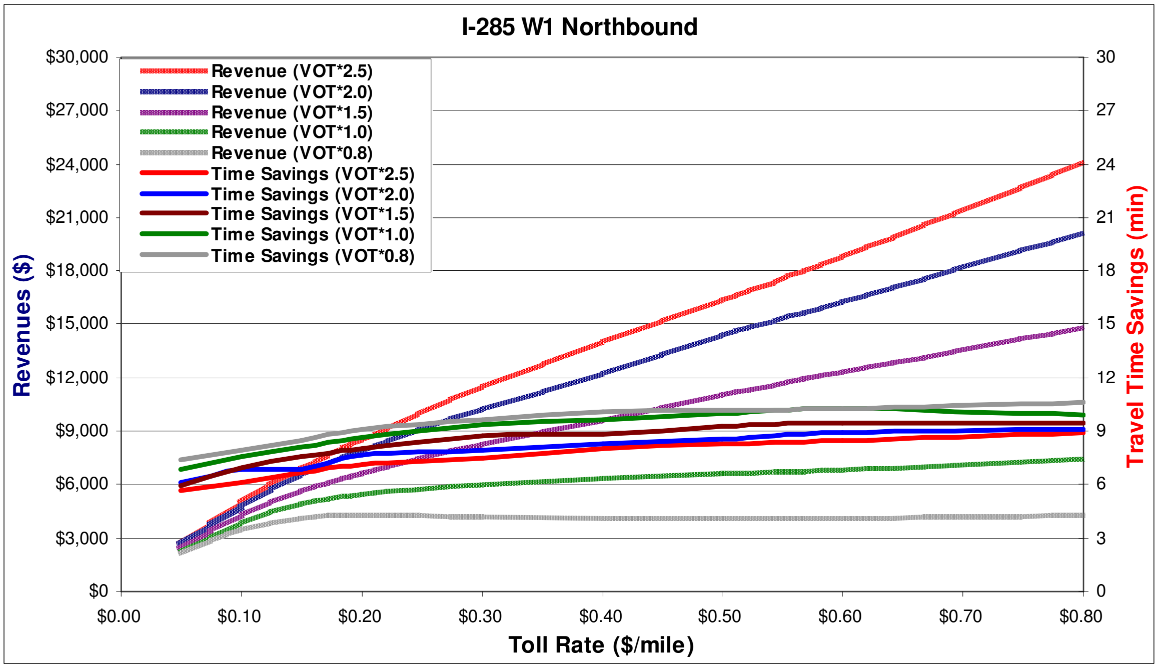


Figure 5-5: Performance Measure Comparison among Various Truckers' Values of Time on I-285W1 Northbound during 2030 PM Peak (Voluntary TOT Lanes)

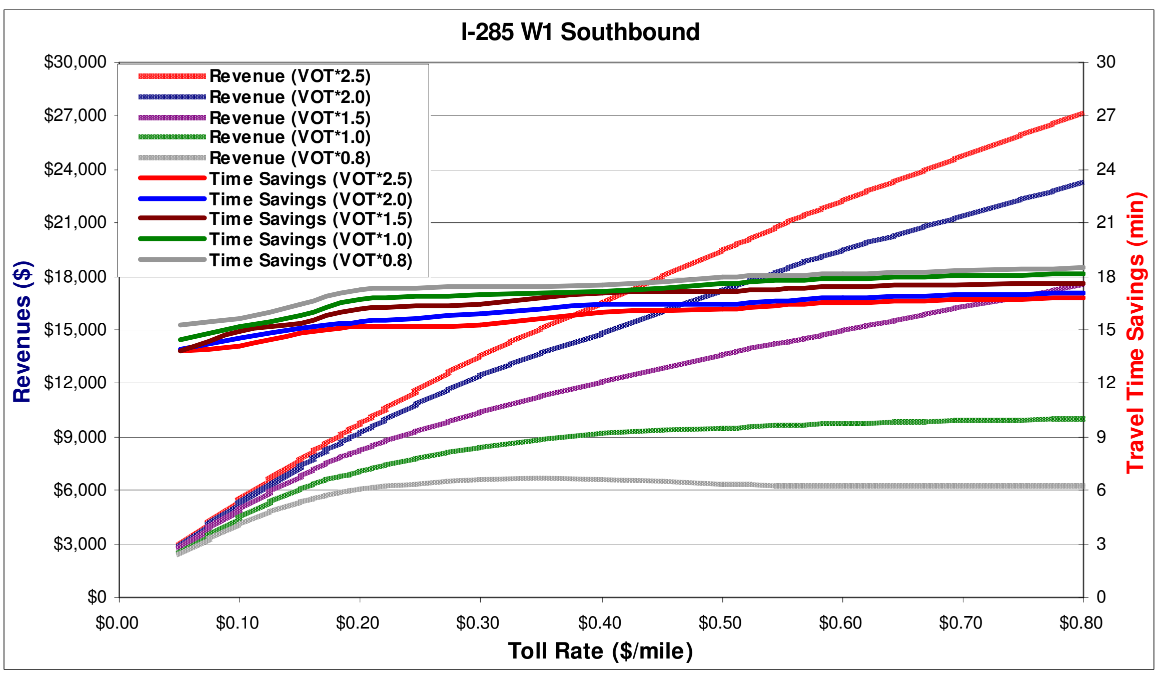


Figure 5-6: Performance Measure Comparison among Various Truckers' Values of Time on I-285W1 Southbound during 2030 PM Peak (Voluntary TOT Lanes)

5.2. A TOT Lane Network in the Atlanta Region

A TOT lane freeway network would presumably provide better connection and accessibility benefits than an individual TOT corridor. This research examined the performance measures of all selected TOT corridors (a combination of 8) in the Atlanta region and compared various scenarios of mandatory or voluntary TOT lanes (two inside lanes in each direction) and adding general purpose lanes (two lanes in each direction) to replace TOT lanes, as shown in Table 5-5 and Table 5-6. Figure 5-7 and Figure 5-8 show the relationship between the utilization rate, revenue and respective toll levels on I-75N1 and I-285W1. A utilization rate of at least 50% in the voluntary TOT lanes is desired to increase the usage of TOT lanes as well as generate revenues and alleviate traffic congestion on the general purpose lanes. Appendix A shows the relationship between toll rates and operational conditions (speed and VMT) as well as revenues.

Based on the optimum toll rates, the results show that mandatory TOT lanes generate higher revenues and greater travel time savings for trucks traveling on TOT lanes than do voluntary TOT lanes. In general, mandatory TOT lanes improve the level of service on general purpose lanes than do voluntary TOT lanes because all through truck trips are forced to travel on TOT lanes. The exception to this improvement is the situation in which a corridor has a large amount of local truck traffic because the shift of through trucks from the general purpose lanes to TOT lanes attracts more local trucks to use "free" general purpose lanes.

In addition, the low utilization rates and toll revenues generated from I-20W, I-85S, and I-75S indicate that direct access to the major freight generators needs to be considered to serve truck trips that originate or terminate within these corridors as well as reduce truck traffic on general purpose lanes. When TOT lanes are added on several corridors including I-285E1, I-285W1, and I-285N, there is still a poor level of service (E and F) on the general purpose lanes and in the HOV lanes. HOV lanes might have to be converted into HOT lanes. Furthermore, compared to adding general purpose lanes, building TOT lanes shows the benefits of improving traffic conditions on general purpose lanes only for corridors with significant truck volumes such as I-75NW and I-285W1.

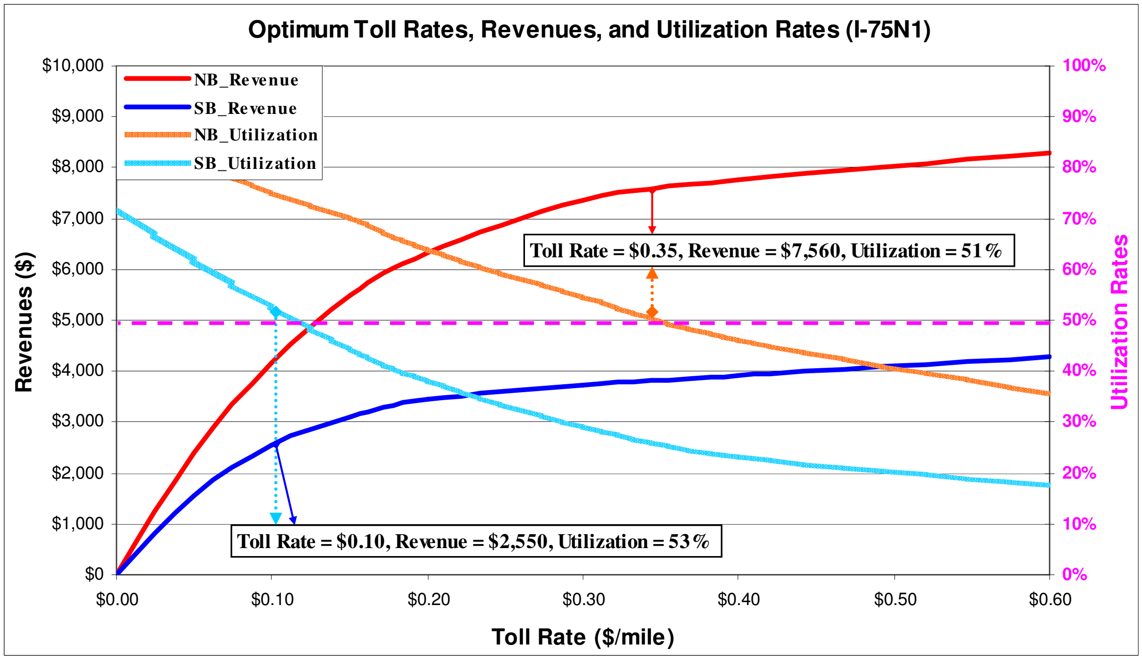


Figure 5-7: Voluntary TOT System in I-75N1 during 2030 PM Peak Period

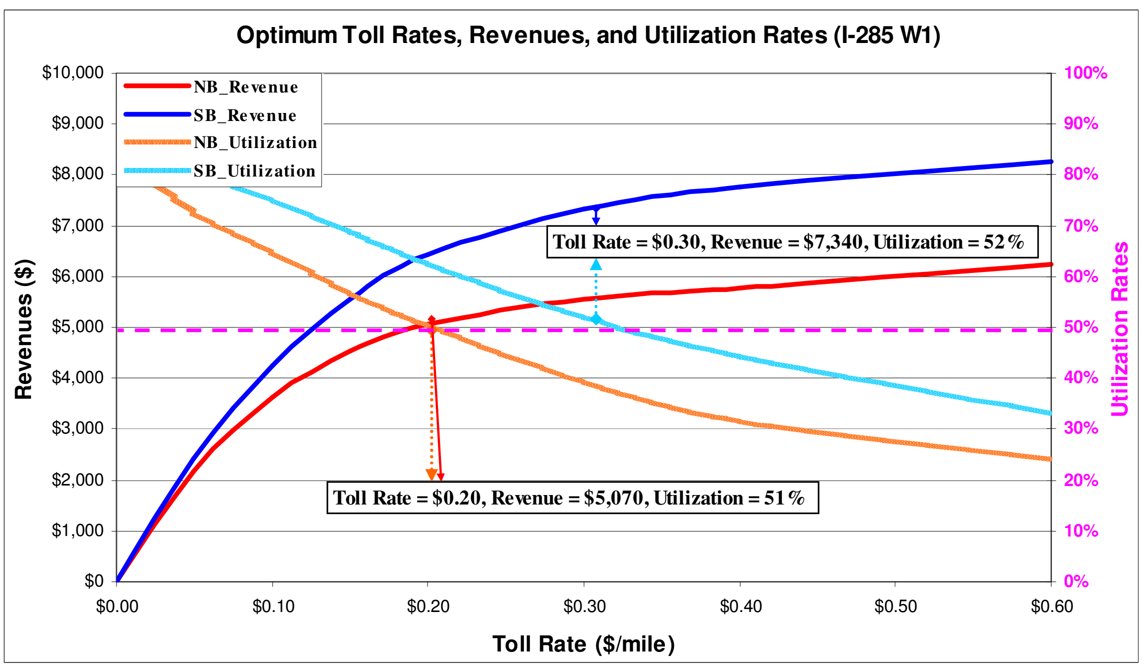


Figure 5-8: Voluntary TOT System in I-285W1 during 2030 PM Peak Period

Table 5-5: Atlanta System Network Performance under Different Scenarios during 2030 PM Peak Period (3:00 – 7:00 PM)

Scenarios	Both Directions	Average Speed (mph)	Total Travel Time (min)	Total Delay (min)	Total Vehicle Miles Traveled	Total Revenues
No-Build Alternative	GP lanes	33	1,049	574	1,474,156	
Add GP lanes	GP lanes	42	689	235	1,762,842	
Voluntary TOT lanes	GP lanes	38	796	355	839,550	
	TOT lanes	60	452	8	713,103	$117,245
Mandatory TOT lanes	GP lanes	39	783	340	730,469	
	TOT lanes	59	462	30	979,909	$165,526

1. Performance measures are derived from optimum toll rates varied by different travel directions
2. Delay is travel time under congested travel speed minus travel time under free-flow speed
3. Vehicle miles traveled includes heavy trucks and medium trucks
4. Total travel time, total delay, total VMT, and total revenues are computed from all TOT corridors in the Atlanta region

Table 5-6: Individual Corridor Performance in the Atlanta System Network during 2030 PM Peak Period (3:00 – 7:00 PM)

Scenarios	Both Directions	Average Speed (mph)	Total Travel Time (min)	Total Delay (min)	Total Vehicle Miles Traveled	Total Revenues
I-20 East						
Add GP lanes	GP lanes	52	37	6	59,231	
Voluntary TOT lanes	GP lanes	44	47	18	37,559	
	TOT lanes	62	29	0.2	38,111	$6,637
Mandatory TOT lanes	GP lanes	45	46	17	35,828	
	TOT lanes	63	29	0.4	52,467	$6,880
I-20 West						
Add GP lanes	GP lanes	53	95	17	258,164	
Voluntary TOT lanes	GP lanes	47	112	33	137,245	
	TOT lanes	60	82	0.6	84,182	$4,207
Mandatory TOT lanes	GP lanes	48	111	33	132,533	
	TOT lanes	61	82	0.9	111,801	$5,590
I-285 East 1						
Add GP lanes	GP lanes	36	54	26	109,642	
Voluntary TOT lanes	GP lanes	32	64	38	55,475	
	TOT lanes	62	27	0.6	57,122	$14,932
Mandatory TOT lanes	GP lanes	32	63	38	47,482	
	TOT lanes	61	27	1.4	79,096	$21,138
I-285 East 2						
Add GP lanes	GP lanes	37	44	21	98,976	
Voluntary TOT lanes	GP lanes	32	54	30	46,014	
	TOT lanes	58	25	0.8	50,948	$12,640
Mandatory TOT lanes	GP lanes	34	50	26	36,233	
	TOT lanes	56	26	1.7	68,264	$17,052
I-285 North 1						
Add GP lanes	GP lanes	34	27	13	61,711	
Voluntary TOT lanes	GP lanes	29	34	19	32,114	
	TOT lanes	57	15	0.4	32,961	$9,952
Mandatory TOT lanes	GP lanes	30	33	18	21,790	
	TOT lanes	54	16	1.4	51,585	$15,501
I-285 North 2						
Add GP lanes	GP lanes	32	30	16	53,417	
Voluntary TOT lanes	GP lanes	28	37	23	27,528	
	TOT lanes	57	16	0.4	28,311	$7,772
Mandatory TOT lanes	GP lanes	28	35	21	21,911	
	TOT lanes	55	16	1.0	41,611	$11,478

Table 5-6 (cont.): Individual Corridor Performance in the Atlanta System Network

Scenarios	Both Directions	Average Speed (mph)	Total Travel Time (min)	Total Delay (min)	Total Vehicle Miles Traveled	Total Revenues
I-285 South						
Add GP lanes	GP lanes	50	14	3	59,383	
Voluntary TOT lanes	GP lanes	44	16	5	25,248	
	TOT lanes	60	11	0.4	27,080	$3,460
Mandatory TOT lanes	GP lanes	49	14	3	16,187	
	TOT lanes	57	12	0.9	37,307	$4,738
I-285 West 1						
Add GP lanes	GP lanes	34	41	20	109,198	
Voluntary TOT lanes	GP lanes	33	45	25	47,150	
	TOT lanes	58	21	0.7	49,797	$12,404
Mandatory TOT lanes	GP lanes	33	44	24	31,136	
	TOT lanes	54	22	2.2	77,658	$19,392
I-285 West 2						
Add GP lanes	GP lanes	35	39	17	128,393	
Voluntary TOT lanes	GP lanes	34	40	19	49,371	
	TOT lanes	59	23	0.7	51,938	$10,108
Mandatory TOT lanes	GP lanes	35	38	17	28,470	
	TOT lanes	55	25	14.9	86,195	$17,354
I-75 North 1						
Add GP lanes	GP lanes	36	39	18	91,800	
Voluntary TOT lanes	GP lanes	36	42	21	44,353	
	TOT lanes	58	22	0.9	47,506	$10,112
Mandatory TOT lanes	GP lanes	36	43	20	33,950	
	TOT lanes	54	24	2.7	77,718	$18,471
I-75 North 2						
Add GP lanes	GP lanes	46	63	20	164,192	
Voluntary TOT lanes	GP lanes	46	66	25	62,321	
	TOT lanes	62	43	0.3	50,962	$3,835
Mandatory TOT lanes	GP lanes	47	65	24	52,761	
	TOT lanes	63	43	0.6	69,824	$4,921
I-75 South 1						
Add GP lanes	GP lanes	45	32	9	78,517	
Voluntary TOT lanes	GP lanes	43	35	12	38,307	
	TOT lanes	60	22	0.1	17,140	$1,494
Mandatory TOT lanes	GP lanes	44	34	11	35,607	
	TOT lanes	61	22	0.2	24,105	$1,619
I-75 South 2						
Add GP lanes	GP lanes	54	49	7	169,259	
Voluntary TOT lanes	GP lanes	51	54	17	72,546	
	TOT lanes	65	37	0.2	36,496	$1,825
Mandatory TOT lanes	GP lanes	51	54	17	66,297	
	TOT lanes	69	37	0.3	48,583	$2,430
I-85 North						
Add GP lanes	GP lanes	41	72	32	192,432	
Voluntary TOT lanes	GP lanes	37	85	48	104,075	
	TOT lanes	62	37	1.3	89,535	$14,045
Mandatory TOT lanes	GP lanes	36	86	49	112,961	
	TOT lanes	63	37	1.3	90,700	$14,324
I-85 South						
Add GP lanes	GP lanes	51	55	11	128,527	
Voluntary TOT lanes	GP lanes	45	66	22	60,244	
	TOT lanes	62	44	0.3	51,014	$3,822
Mandatory TOT lanes	GP lanes	45	66	22	57,323	
	TOT lanes	62	44	0.4	62,995	$4,638

5.3. Feasibility of a TOT Lane Network in Georgia

Although the focus of this research was on one corridor and on the Atlanta regional freeway system, it is interesting to examine how the methodology could be used to examine the feasibility of TOT lanes at the state level. In this case, a statewide travel demand model would have to be used to determine future volumes on state freeways. Such a modeling approach, however, has some limitations. Each traffic analysis zone in the statewide model represents one county, thus the internal-to-internal trips in the zone will not be very accurate. The network in the statewide model also does not include local roads and is less detailed than a metropolitan planning organization (MPO) model. Thus, a statewide model cannot analyze detailed origins and destinations of intercity freight movements. However, a statewide model is still appropriate to analyze long-distance truck trips which are beyond the forecast area of a MPO model, for example, the external-to-external truck trips traveling through the metro Atlanta region.

The 2035 Georgia statewide travel demand model was used in this research to identify candidate TOT corridors. This is a different model from the 2030 ARC travel demand model utilized in the assessment of individual TOT corridors and the regional TOT network. For example, truck data in the statewide model covering urban and rural interstates are different from the regional model data that includes most urban interstates. Also, the statewide model has the limitations in assigning truck trips with origins and destinations within a same county, which would cause some missing local truck trips to and from the same county in the metro Atlanta region. Furthermore, data collection of truck classification counts used to validate the statewide model is likely different from counts used in the ARC model, which causes a different number of truck trips to be assigned to the highway network. Finally, additional lanes in each direction on parts of I-75, I-85, I-20 east, I-20 west, and I-575 that are incorporated in the Georgia DOT long range program are coded only in the statewide model, not in the ARC model. Therefore, the threshold values of screening criteria and the results of selected TOT corridors might be different even though applying the same methodology to the same corridors. The following sections discuss four primary screening criteria including low levels of service, high truck volumes, high truck percentages, and truckers' willingness-to-pay, and a secondary criterion of high truck-related crashes.

5.3.1. Level of Service

Corridors that experience severe congestion of an average level of service E or F during the PM peak period in the projected year 2035 were identified as candidate TOT lanes, as shown in Figure 5-9. These congested corridors included I-75 (from north Georgia boundary to Macon County), I-285 perimeter (except I-285W), I-85N (from I-285N to I-985), I-85S (from I-285S to Atlanta regional boundary), part of I-20W and I-20E, I-985, I-95, I-575, and GA 400.

5.3.2. High Truck Volume

The mean daily truck volume including medium and heavy trucks in both directions on Georgia interstate highways in the projected year 2035 is approximately 16,560. More than 50% of selected highway links have truck volumes greater than 17,000. Therefore, corridors with daily truck volumes over 17,000 are selected as candidate TOT lanes, as shown in Figure 5-10. These corridors include I-75 (through all of Georgia), I-85 (from northeast Georgia boundary to Coweta County), I-20W, I-95, and parts of I-20E and I-16.

5.3.3. High Truck Percentage

The mean daily truck percentage including medium and heavy trucks in both directions on Georgia interstate highways in the projected year 2035 is approximately 32% of all traffic. More than 50% of selected highway links have a truck percentage greater than 28%. Therefore, corridors with a daily truck percentage over 28% are selected as candidate TOT lanes, as shown in Figure 5-11.

5.3.4. High Truck-Related Crashes

The mean truck-related crash rate including fatality, injury, and property damage only (PDO) from 2000 to 2005 on Georgia interstate highways is approximately 77 crashes per 100 million vehicle-miles traveled (VMT). This statewide average crash rate is greater than the regional average crash rate of 63 per 100 million VMT, because through heavy trucks are not allowed to travel inside I-285 without permits. The top 50 and top 100 truck-related crash locations in the statewide interstate system experience more than 497 and 265 crashes per 100 million VMT, respectively. Most high truck-related crashes occurred on I-285, I-85N, I-75N, I-75S, the I-475 bypass around Macon, and I-95 near the port of Savannah. An interstate segment that experiences a total crash rate of fatality, injury, and PDO over 77 crashes per 100 million VMT was identified as a high truck-related crash location, as shown in Figure 5-12.

5.3.5. Trucker's Cost Saving Threshold

Highway segments with potential improvements for congested travel time during the PM peak period in the projected year 2035 are selected as candidate TOT lanes if the monetary value of travel time savings gained from using an average corridor speed is greater than the 90th percentile minimum cost savings threshold. Based on Figure 4-15 (as noted in Chapter 4), the 90th percentile minimum cost savings threshold of approximately \$3 is derived from the distribution curve of truckers' willingness-to-pay. Most qualified corridors appear within the metro Atlanta region, I-95 around the port city of Savannah, and I-75S between I-16 and Florida, as shown in Figure 5-13.

5.3.6. Combining the Screening Criteria

Four corridors with specific extents/boundaries on the Georgia interstate highway system that meet screening criteria are shown in Table 5-7 and Figure 5-14. Most candidate TOT corridors including I-75N, I-85N, I-75S, and I-95 are located outside the

Atlanta region. These areas include northern Georgia to Tennessee, northeast Georgia to South Carolina, the Macon area between the Atlanta area and Florida, and the port of Savannah. From the engineering viewpoint, gaps along a TOT corridor should be filled with TOT lanes to combine these individual TOT links into a TOT corridor and to provide the continuity. Also, the boundary of TOT corridors should be extended to system interchanges in order to assure system connectivity and to serve high locations of access and egress, as shown in Figure 5-15.

Table 5-7: Potential TOT Corridors on Georgia Interstate Highways

Screening Criteria	Potential TOT Corridors	
1. Level of service (pm peak) = E ~ F	1.	I-75 N (from I-575 to state north boundary)
2. Truck volume (daily) > 17,000	2.	I-85 N (from I-985 to state northeast boundary)
3. Truck percentage (daily) > 28%	3.	I-75 S (from I-675 to US Highway 41 in Tift county)
4. Truck-related crash rate (annual) > average statewide crash rate	4.	I-95 (from state boundary in Chatham county to SR 251 in McIntosh county)
5. Monetary value of travel time savings (pm peak) > 90^{th} percentile truckers' cost saving threshold		

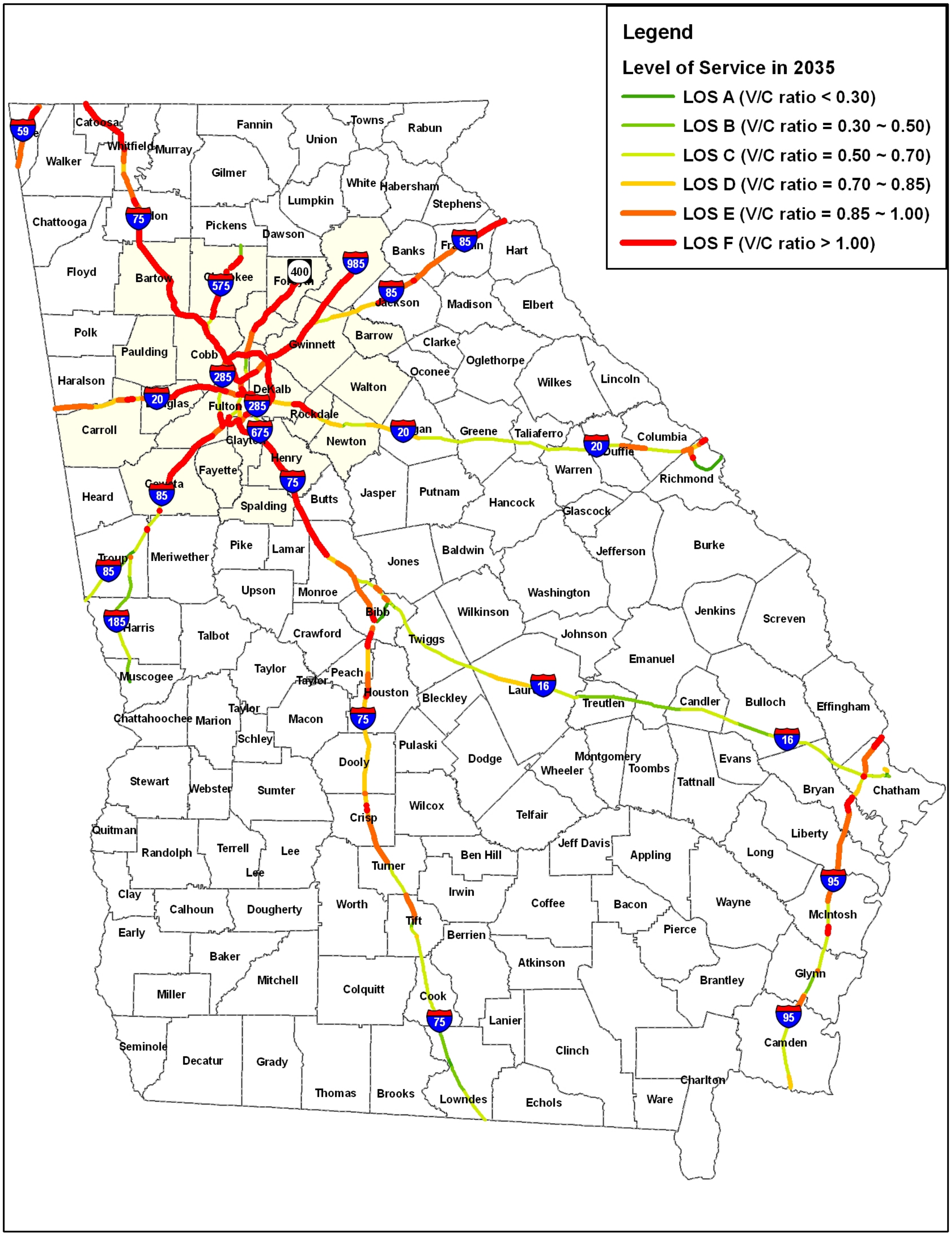


Figure 5-9: Forecast 2035 Level of Service on Georgia Interstate Highways (PM Peak)

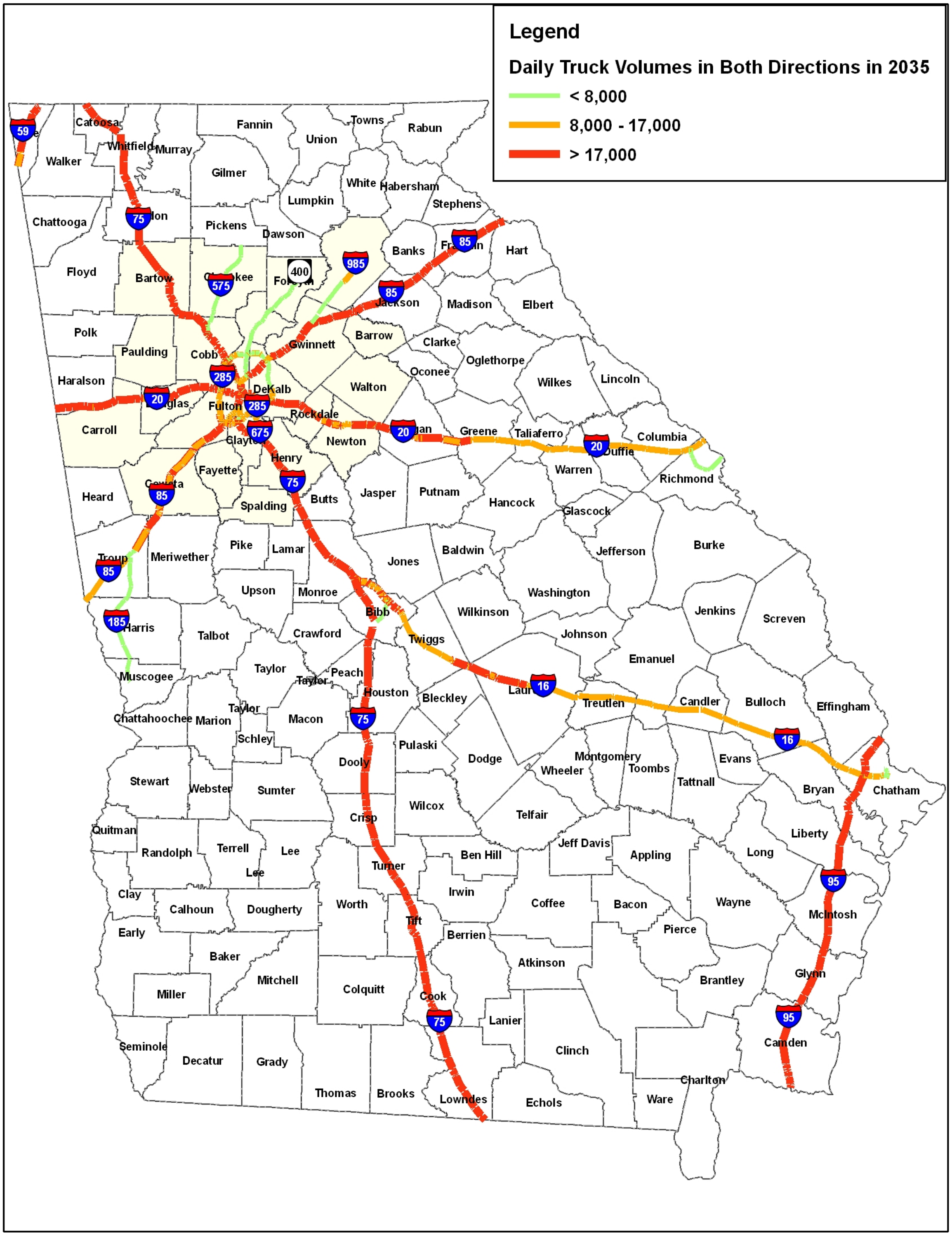


Figure 5-10: Forecast 2035 Daily Truck Volumes on Georgia Interstate Highways

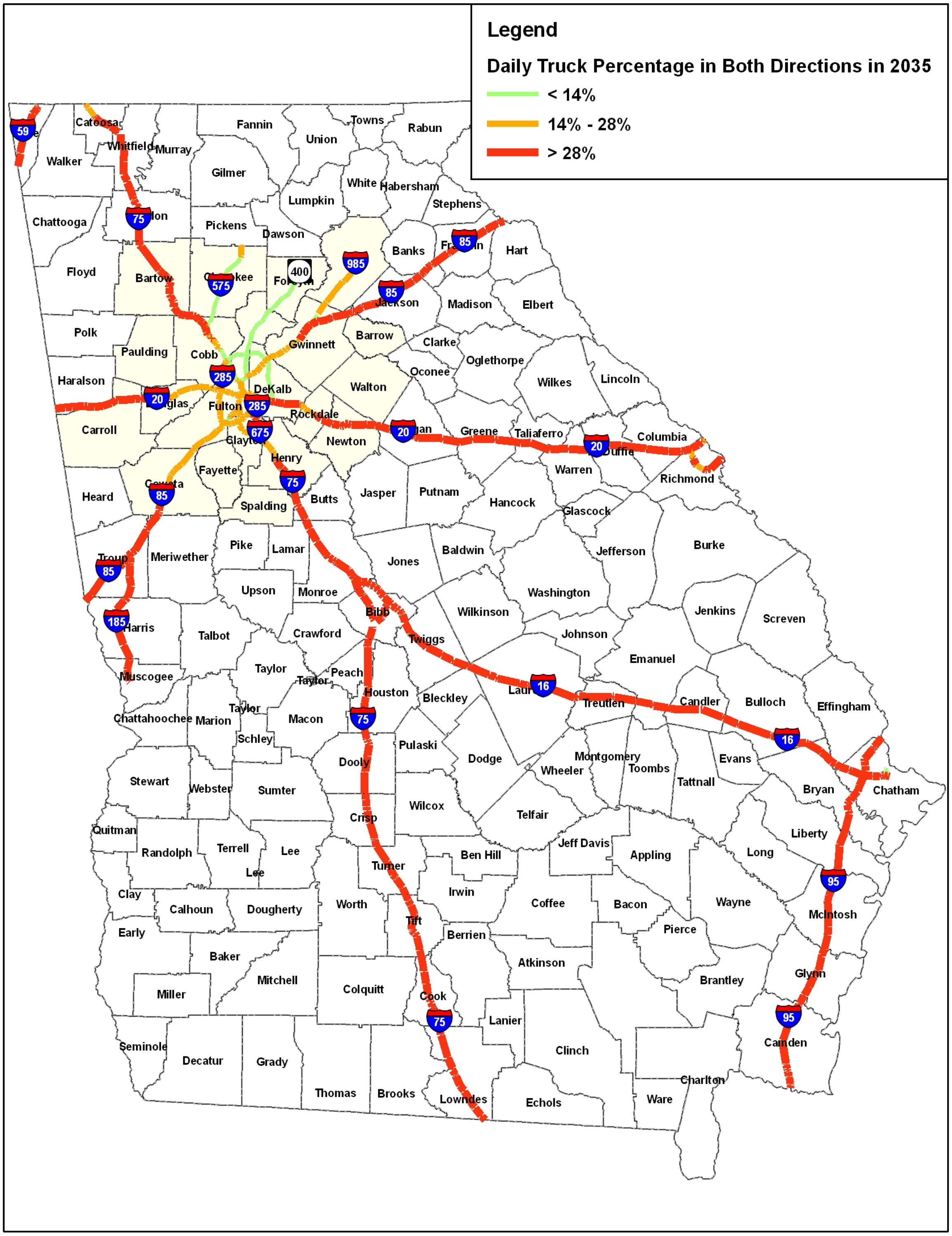


Figure 5-11: Forecast 2035 Daily Truck Percentage on Georgia Interstate Highways

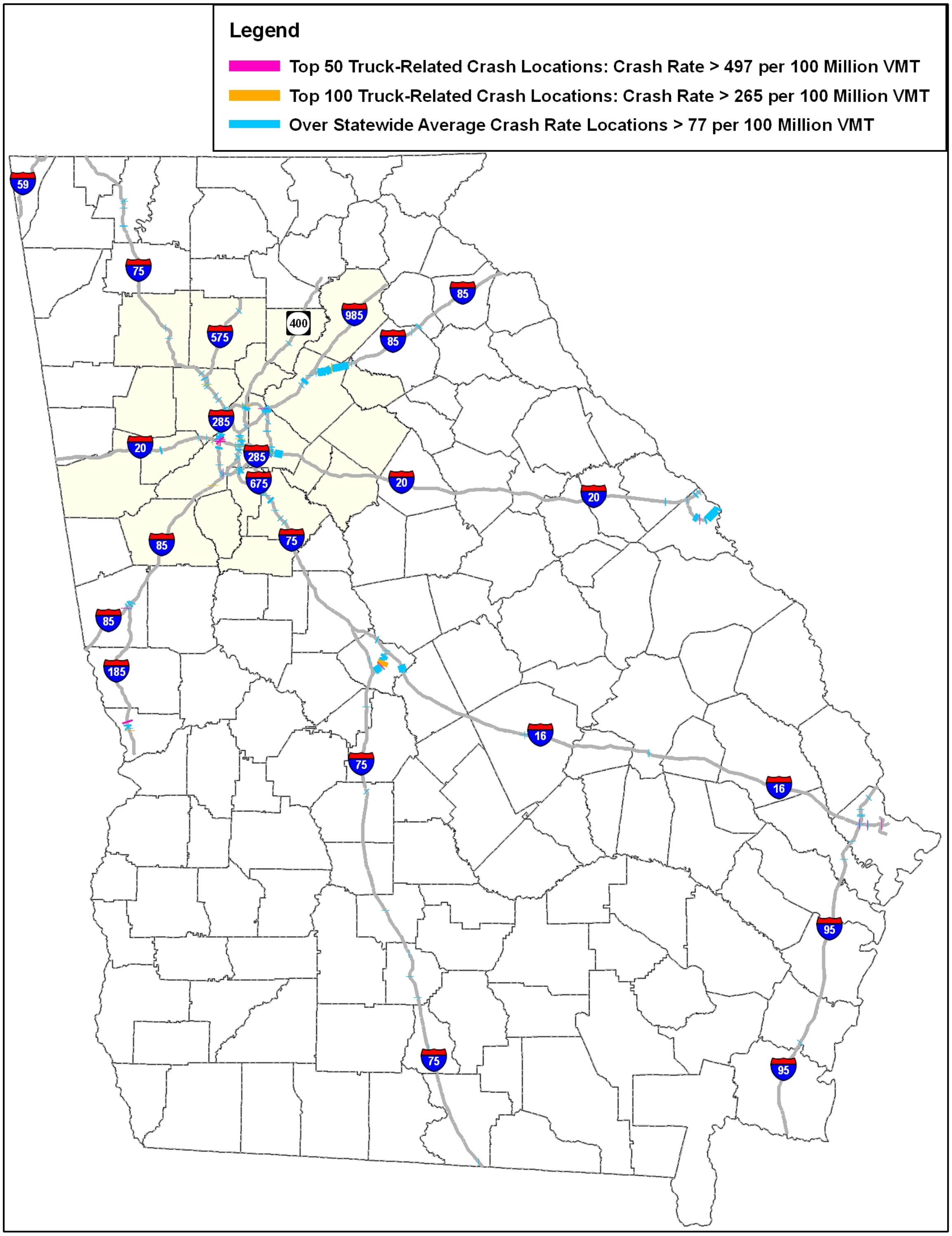


Figure 5-12: Locations of Existing High Truck-Related Crashes on Georgia Interstate Highways

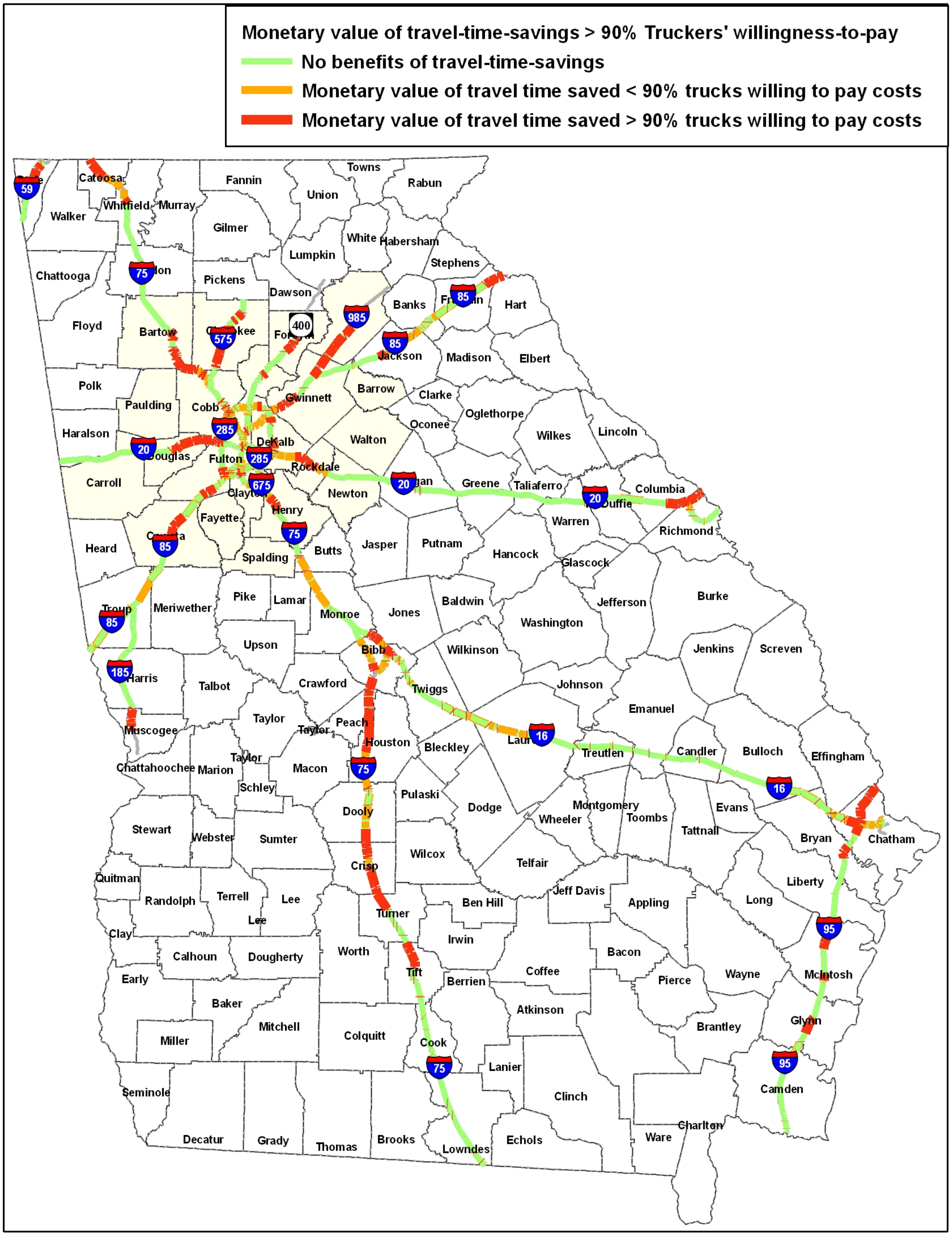


Figure 5-13: Forecast 90% Truckers' Willingness-to-Pay Costs for Travel Time Savings on Georgia Interstate Highways in 2035

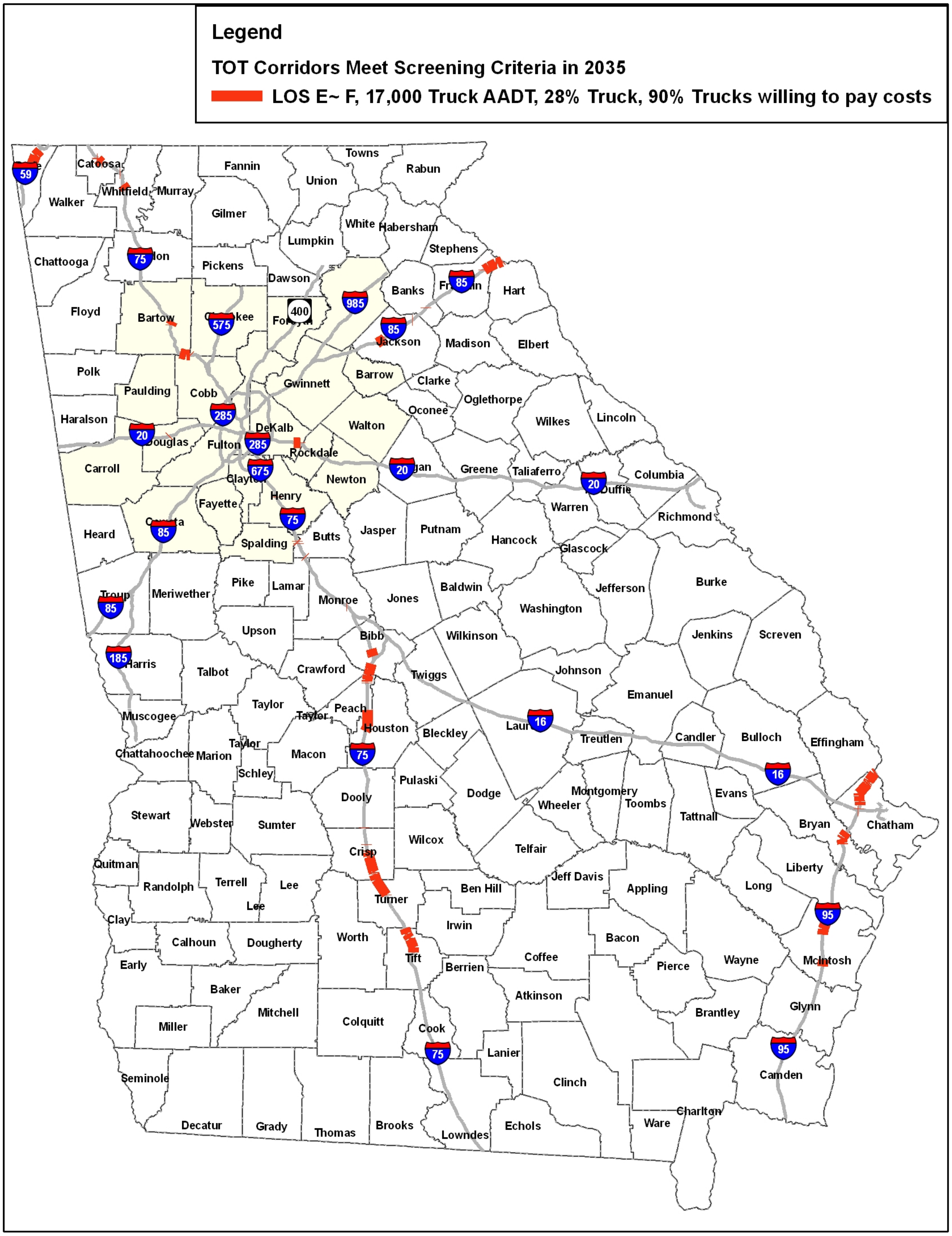


Figure 5-14: TOT Lane Corridors Selected by Screening Criteria on Georgia Interstate Highways in 2035

Figure 5-15: Potential TOT Lane Corridors on Georgia Interstate Highways in 2035

5.4. Summary

This chapter summarized the results of an application of the assessment criteria for incorporating acceptable traffic operational conditions, safety improvements, and revenue generation to pay for transportation improvements to identify feasible TOT corridors under different scenarios. The same methodology can be applied to different geographic regions as a basis for determining individual corridor and statewide TOT lanes.

The results of examining I-285W at different geographic levels indicate that a regional TOT network is an efficient way to better manage traffic conditions on freeways than an individual TOT corridor because of more optional TOT routes for truckers to choose from. For example, comparing the I-285W in the Atlanta TOT system freeways with building only an individual I-285W TOT corridor, the TOT freeway system shows better levels of service and lower delays on TOT lanes and GP lanes.

Additionally, the study results illustrate that most TOT corridors still have excess capacity available for both voluntary and mandatory use, indicating the self-financing could be a challenge in implementation. Although mandatory use of TOT lanes generates higher toll revenues and more easily controls truck traffic flow, this policy may not gain the support from the trucking industry.

In terms of the benefits for increased freight productivity from less delay and more travel time savings for trucks traveling on TOT lanes, the performance of voluntary TOT lanes is better than that of mandatory TOT lanes and adding general purpose lanes. Regarding improvements on GP lanes, adding general purpose lanes instead of building TOT lanes results in better performance measures for most corridors without high truck travel demand; however, the safety issue still exists because of the mixed truck-car traffic flows. Considering high truck-related crashes, the following corridors -- I-75NW, I-75S, I-285W1, and I-285E -- would have high priority for building TOT lanes.

Candidate statewide TOT corridors using the 2035 Georgia statewide travel demand model exclude almost all of the regional TOT corridors (except the I-75 north) from the 2030 ARC travel demand model. The difference might be caused by future improvement projects coded in the highway network between different projected years (2030 and 2035), truck counts from different origin-destination (O-D) surveys, and the GDOT database applied in the model validation process. The results also indicate that a regional model performs more accurately in forecasting regional truck trips than does the statewide model. Therefore, the statewide model should be used to identify initial truck lane needs, and should be supplemented and refined by MPO models (e.g., those for ARC, Savannah, Macon, etc.). An MPO model should be used to develop detailed screening criteria for candidate TOT corridors.

CHAPTER 6

PLANNING GUIDANCE

Currently, there are very few guidelines available for implementing TOT facilities. Also, strategies for the critical issues regarding planning, design, and operation of TOT facilities at different geographic levels have not been developed thoroughly. This chapter addresses implementation issues such as the selection of potential TOT lanes, a policy of mandatory versus voluntary truck use, design of lane placement and access locations, safety, and tolling strategies. Furthermore, TOT planning guidance is presented to provide transportation engineers with information considering TOT projects as well as effectively implementing TOT infrastructure. This guidance will also help achieve the goals of alleviating traffic congestion, reducing truck-related crashes, and generating additional revenue to fund TOT projects.

6.1. Strategies for Issues Regarding Implementation of TOT Lanes

The following sections address issues regarding the planning, design, and operation and associated strategies for the implementation of TOT lanes at the corridor, region, and state levels.

6.1.1. Example Issues of Planning

TOT Lane Screening: How to determine the feasibility of a TOT lane that is expected to improve congestion levels, increase safety, and generate revenues?

- A screening process developed in this research is applicable for different geographic levels to identify candidate TOT lanes. This process uses a geographic information system (GIS)-based analysis to identify feasible TOT lane candidates and also to determine the extent of the TOT lane in that corridor.

6.1.2. Example Issues of Engineering Design

Number of Lanes: How to determine the number of lanes in each direction on TOT lanes?

- Building one or two (or more) TOT lanes in each direction is dependent on the acquisition of right-of-way, the comparison of highway capacity and truck traffic demand, and the requirement of incident management. For example, one TOT lane in each direction might be appropriate for a corridor without enough right-of-way or significant truck traffic, but it might cause access difficulty for freeway incident management because of the large size and weight of heavy trucks.

  A design AADT of daily truck volumes should be established to justify building a minimum of two TOT lanes in each direction. A volume-to-capacity ratio (V/C) of at least level of service C and utilization rate of at least 50% on TOT lanes can be used to determine building one lane or two lanes. The number of TOT lanes should be consistent throughout the length of a corridor between system interchanges and might be varied by corridors at regional and statewide levels.

Lane Placement: How to determine the trade-offs between operational efficiency and construction cost regarding placing TOT lanes in the inside lanes (in or adjacent to the median) or in the outside lanes of a freeway?

- Inside or outside TOT lanes can be assessed based on the percentage of through truck volume and the potential relocation of existing HOV lanes. The placement of TOT lanes should be consistent along the entire corridor and might be varied by corridors at regional or statewide levels. Multiple access points should be considered to serve local truck traffic once TOT lanes are placed at the outside lanes. Exclusive direct access ramps should be considered to cross over adjacent lanes once TOT lanes are placed in the inside lanes.

Barrier Separation: Should TOT lanes be physically separated from general purpose lanes by concrete, pavement, grass, or paint stripe?

- Based on an evaluation of safety and cost, lane separation should be consistent throughout the length of a corridor and might be varied by corridors at regional and statewide levels depending on the available right-of-way in urban or rural areas. Concrete barriers, pavement, and grass are much safer than paint stripes; however, the construction cost and available right-of-way are larger.

Access Location: What requirements are needed to determine appropriate locations for access points to TOT lanes?

- The locations of multiple access points within a TOT corridor are usually determined by freeway configuration, truck trip patterns of origin and destination, and connection with large freight generators. The location may connect with interstate highways or major arterials such as U.S. highways or state highways to provide access to TOT lanes.

  In addition, entry and egress points should be separated to avoid weaving conflicts. Exclusive interchanges with direct access ramps, dependent on right-of-way acquisition and freeway configuration, can remove the weaving movements between TOT lanes and general purpose lanes as well as maintain a consistent travel speed through the interchange area. A special design must be considered to accommodate the minimum turning radius for longer combination vehicles' (LCVs), such as double or triple trailers, maneuvers on ramps.

Truck Parking Area: How to determine the location of truck parking areas along a TOT corridor?

- Increased truck parking resulting from more truck trips causes safety and legal issues. For example, due to lack of roadside truck parking areas or rest areas nearby, some delivery trucks park on interchange ramps and limit other drivers' sight distance.

A staging area can provide trucks with parking and other services. The location of a staging area should be located alongside the right-of-way and connect with exclusive access ramps to TOT lanes at interchanges with high daily truck volumes.

6.1.3. Example Issues of Operation

Mandatory or Voluntary: How to determine whether to mandate trucks to use TOT lanes or to allow trucks the option?

- TOT lanes are dedicated for heavy trucks or medium trucks (depending on policy) with the payment of a toll. Mandatory use of TOT lanes may not gain the support from the trucking industry because truckers have a high sensitivity to a toll cost. Also, truckers would not pay additional cost for time periods or some highway segments without the benefit of travel time savings.

  One strategy is to use voluntary TOT lanes along with a financing approach based on public-private partnerships that ensures the benefits of increased trip reliability and decreased delivery times, allows bigger size and weight of longer combination vehicles (LCVs), and provides truck parking and rest areas connecting with direct access ramps to TOT lanes.

Tolling Strategy: How to determine a pricing strategy of using flat tolls, variable tolls, or dynamic tolls on TOT lanes?

- A dynamic pricing strategy that charges a toll based on actual real-time traffic conditions on TOT lanes requires a system of real-time monitoring and communication to potential users. Such systems exist in southern California and have been used with some success. An easier pricing strategy is to vary toll rates by different time periods (peak/off-peak) or travel direction (dependent on policy decision) with a pre-determined schedule, which can also manage traffic demand and generate revenues better than using a flat toll rate.

An optimum toll rate should not only focus on generating maximum revenues, but also maintaining traffic conditions at a level of service C or D on the TOT lanes and creating at least a 50% utilization rate of TOT lanes to justify investment in TOT lanes and improve congestion level on general purpose lanes. Additionally, an optimum toll rate should divert trucks from local roadways to TOT lanes and thereby reduce local traffic congestion as well as accidents. Toll rates will likely vary among corridor, regional, and statewide levels based on different truck trip characteristics.

Speed Limit: Should TOT lanes offer truckers higher speed limits than general purpose lanes?

- The speed limit is defined by state legislatives, based on recommendations from the state DOT. Most transportation agencies base speed limits on the 85th percentile speed of all traffic. TOT lanes could offer trucks a higher speed limit (> 55mph on urban interstates) than general purpose lanes because the uniform traffic flow could allow a higher free-flow speed. For TOT lanes with barrier separation, speed variances caused by an increased truck speed limit will be less of a safety issue to car drivers.

  Truck speed differentials between TOT lanes and general purpose lanes will be determined based on state policy, safety considerations, and the benefits of travel time savings. Due to the limitation of heavy trucks' turning maneuvers, reducing posted speed limits for trucks driving on entry and exit ramps can decrease truck accidents. The speed limit of TOT lanes should be varied by area types (urban and rural) and freeway configuration at the corridor, regional and statewide levels.

6.2. Implementation Steps for TOT Lanes

This section presents planning guidance for implementing TOT lanes. An iterative process of implementing TOT lane candidates are developed based on the interpretation of modeling results, as shown in Figure 6-1. Specific steps of engineering design and operation are not discussed in this research.

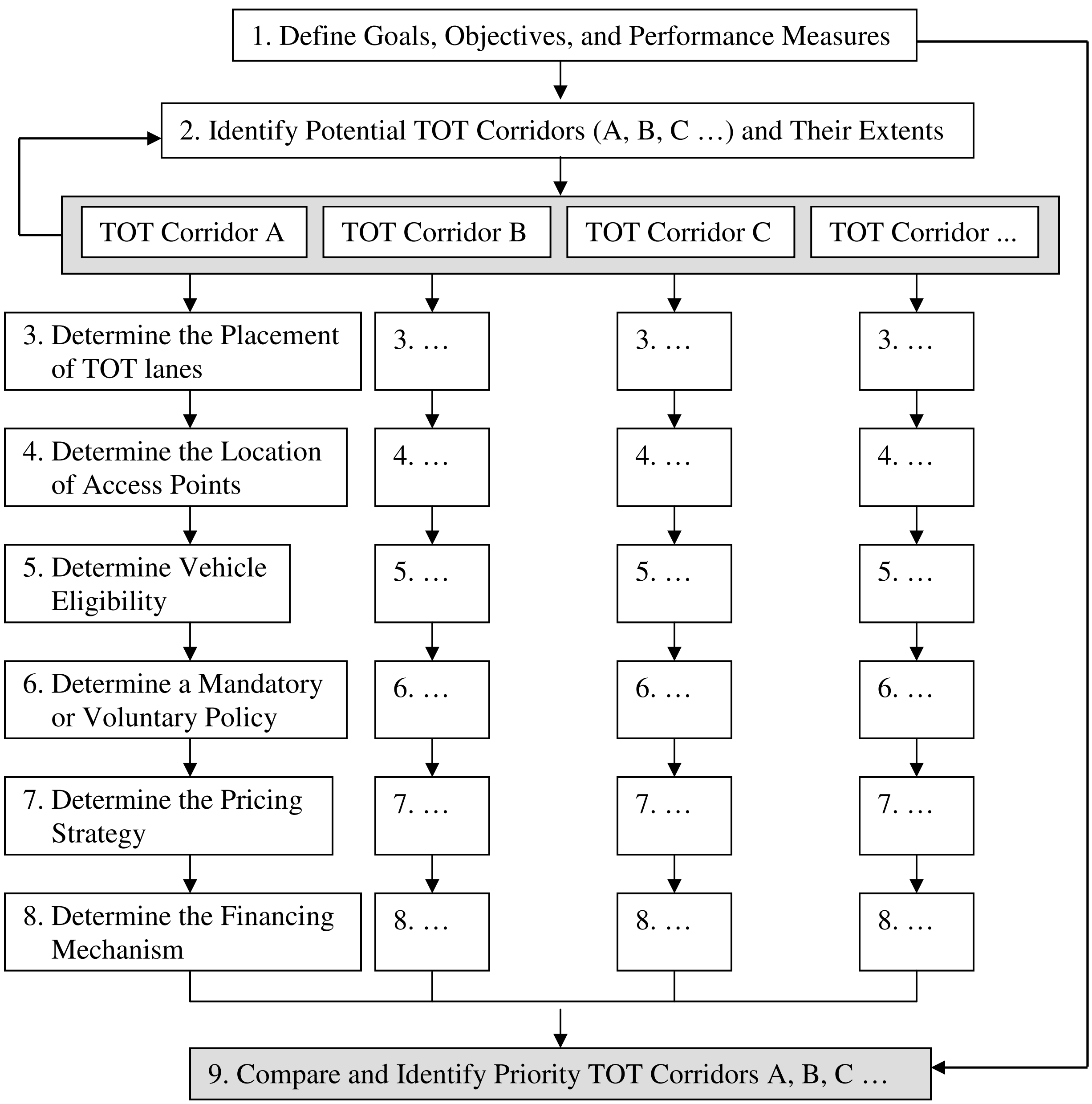


Figure 6-1: An Iterative Process of Implementing TOT Lane Candidates

6.2.1. Step One: Define Goals, Objectives, and Performance Measures

The primary goals of implementing TOT lanes include: (1) improving traffic operational efficiency on both TOT lanes and general purpose lanes, (2) increasing travel safety for both auto and truck drivers, (3) enhancing the productivity of freight movement and promoting economic development, (4) creating self-financing potential, and (5) decreasing truck traffic impacts to the environment.

Several objectives associated with these goals include (1) providing an acceptable travel condition on TOT lanes, (2) reducing truck-related crashes, (3) increasing truck trip reliability and providing benefits of travel time savings, (4) generating revenues to support capital, operating, and maintenance costs, and (5) mitigating air pollution by improving stop-and-go truck traffic flow.

Performance measures that are defined to achieve these objectives include (1) maintaining a travel speed of level of service C or D during peak periods on TOT lanes, (2) reducing the truck related crash rate (fatality, injury, and property damage only) on each TOT corridor being lower than the regional, statewide, or national average, (3) producing a travel time saving benefit greater than trucker's toll cost threshold, (4) providing convenient access to major truck trip generators along a TOT corridor and efficient connectivity between TOT corridors, (5) increasing toll revenues by creating at least a 50% utilization rate of TOT lanes, and (6) generating a truck diversion rate greater than 0% by increasing truck vehicle-miles traveled (VMT) on TOT lanes and reducing truck VMT on general purpose lanes as well as parallel local routes.

6.2.2. Step Two: Identify Potential TOT Corridors and Their Extents

The second step is to identify TOT lane candidates by applying a screening process. Four primary criteria are employed to identify the corridor feasibility for TOT lanes and determine the extent of TOT lanes in the corridor. These criteria include (1) level of service, (2) truck volumes, (3) truck-to-total vehicle volume ratios, and (4) truckers' cost saving threshold. Due to the difficulty in forecasting future truck-car crash rates, a secondary criterion of existing truck-related crash rates was used to support the safety benefits of TOT lane candidates. Data associated with these criteria need to be collected, particularly using a stated preference survey to establish heavy-duty and medium-duty truckers' willingness-to-pay distribution curves for candidate TOT corridors.

Freeway segments in the projected year that satisfy the following four criteria simultaneously are defined as a TOT candidate: (1) a level of service equal to E or F during the PM peak period, (2) daily truck volumes greater than a threshold volume of the top 50% of all regional (or statewide) links' truck volume, (3) daily truck percentage greater than a threshold percentage of the top 50% of all regional (or statewide) links' truck percentage, and (4) monetary value of travel time savings during the PM peak period greater than the 90th percentile truckers' cost savings threshold, which is derived from the truckers' willingness-to-pay distribution curve. Travel time saved by using a TOT lane will depend on the speed that is experienced in the TOT lane. The target average corridor speed is a fairly conservative assumption, because the value of time saved would be much less than that likely to be achieved if the TOT lane was at free flow speed. A desired travel speed associated with levels of service C or D in the TOT corridor, which is much higher than the average corridor speed, might be considered in some severely congested corridors to improve operational efficiency.

Based on these four screening criteria, TOT eligible segments would be identified. Gaps within the boundary of a TOT corridor should be filled with TOT lanes to provide connectivity. Gaps between TOT corridors should be filled with TOT lanes reflecting the connection of system interchanges and based on truck flows.

Freeway segments that meet the following criterion are identified as having safety improvement potential: experienced a truck-related crash rate per 100 million vehicle miles traveled during a certain years period (at least three years) greater than a threshold of regional (or statewide) average crash rate. A priority ranking of the top 50 or top 100 high truck crash locations can provide sufficient information for the decision maker to plan the allocation of the available budget among all TOT corridors selected from the four major screening criteria.

6.2.3. Step Three: Determine the Placement of TOT lanes

The placement of TOT lanes on the inside or outside lanes is primarily dependent on the percentage of through truck trips in the corridor and the need to relocate existing HOV lanes. Inside (leftmost) lanes are appropriate for a high percentage of through truck traffic and long-haul truck trips with trip origins and destinations outside the corridor. Outside (rightmost) lanes are appropriate for a corridor serving a lot of local truck traffic and short-haul truck trips with trip origins or destinations within the corridor.

Based on the Atlanta case, a select link analysis approach can be used to identify through truck trips along each corridor. The results suggest that inside TOT lanes should experience at least 50% daily heavy-truck volumes traveling through a corridor. Outside TOT lanes or inside TOT lanes providing multiple direct access interchanges are designed for a corridor with through daily heavy-truck volumes less than 30%. As for the percentage of through truck volume between 50% and 30%, the traffic engineer's judgment should be used to determine the inside or outside placement of TOT lanes.

In addition, the evaluation of inside TOT lanes needs to consider the relocation costs and construction impacts on HOV lane users if HOV lanes are not turned into TOT lanes. Traffic engineers may consider placing TOT lanes between HOV lanes and general purpose lanes. In this design, both HOV lanes and TOT lanes need exclusive access ramps to avoid weaving conflicts.

6.2.4. Step Four: Determine the Location of Access Points

Most freight flows originate or terminate at the location of major freight generators such as warehouse and distribution centers, airports, seaports, and intermodal rail yards.

TOT lanes that are intended to serve long-haul or through truck trips usually provide access ramps at the junction (system) interchange instead of at a regular interchange. However, if there are several logistics facilities along the TOT corridor, dedicated interchange ramps that connect with major access roads to those facilities need to be considered. Major access roads include U.S. highways and state routes having large volumes of truck traffic. If a TOT corridor does not provide efficient accessibility to these facilities, truckers will seek alternative routes.

Based on the Atlanta case, an access point within a TOT corridor is considered once the percentage of daily through truck volume is less than 30% of all truck traffic. Other locations for access points may include connections with truck staging areas for parking, rest, and other services.

6.2.5. Step Five: Determine Vehicle Eligibility

TOT eligibility will certainly include heavy trucks, particularly for a corridor with a large amount of heavy truck traffic. However, a TOT lane with excess capacity does not optimize the use of the transportation investment. Considering the continuing growth of medium trucks for the wide demand of local delivery such as just-in-time delivery service in urban areas, allowing medium trucks to use TOT lanes on a voluntary basis will reduce traffic congestion on the general purpose lanes and increase the usage as well as toll revenues.

TOT lanes with an acceptable operational condition of level of service C comes with a volume-to-capacity (V/C) ratio of approximately between 0.5 and 0.7. Therefore, an urban or rural TOT corridor with excess capacity (operating at less than 50% of corridor capacity) should incorporate medium trucks into TOT lane eligibility.

6.2.6. Step Six: Determine a Mandatory or Voluntary Policy

Mandatory TOT lanes are usually opposed by the trucking industry and may cause truckers to seek alternative free routes to avoid a toll. Voluntary TOT lanes are more acceptable to truckers if the benefit of travel time savings can match their toll costs. However, not every highway segment along a TOT corridor can provide such time saving benefits, particularly in rural areas or off-peak periods. Therefore, ensuring that TOT lanes provide congestion-free travel, reliable trips, efficient incident management, and perhaps allow larger truck sizes and weights will encourage more trucks to use voluntary TOT lanes.

6.2.7. Step Seven: Determine the Pricing Strategy

Variable pricing that varies toll rates based on different time periods or travel directions can manage traffic congestion and provide greater revenues than a flat fee. Determining an optimum toll rate is important for a TOT lane having excess capacity to sell to trucks that are willing to pay a reasonable toll fee. Derived from a travel demand model that differentiates toll rates by time-of-day (morning and afternoon peak periods; midday and night off-peak periods) and travel directions, four objectives are used to determine toll rates for TOT lanes.

(1) Maximum toll revenues: To create the potential for self-financing TOT lanes, the selection of toll rates should generate maximum revenues to cover operating and maintenance costs, and some portion of capital costs.

(2) Acceptable level of service: To attract trucks to TOT lanes, the selection of toll rates should maintain a travel speed associated with LOS C or LOS D on TOT lanes.

(3) High utilization rate: To justify transportation investments and reduce traffic congestion on general purpose lanes, the selection of toll rates should create a utilization rate of TOT lanes at least greater than 50%. A utilization rate is defined as

truck volumes on TOT lanes divided by total truck volumes on the freeway (general purpose lanes and TOT lanes), computed as below:

$$\text{Utilization rate} = \frac{\text{Truck volume on TOT lanes}}{\text{Total truck volume on Interstate (general purpose lanes + TOT lanes)}}$$

(4) Truck diversion rate: To attract trucks from local roadways to TOT lanes and reduce local traffic congestion as well as accidents, toll rates should produce a truck diversion rate greater than 0%. The truck diversion rate is defined as the change in truck volumes before and after building TOT lanes, computed as below:

Truck diversion rate =

$$\frac{\text{Difference of total truck volume on Interstate between after and before building TOT lanes}}{\text{Total truck volume on Interstate before building TOT lanes}}$$

It might be difficult to achieve these four objectives simultaneously, particularly for a TOT corridor without significant through truck volumes, which causes a utilization rate lower than 50% even providing a low toll rate during peak periods. This situation can be improved by providing access connections to major freight generators along this corridor and thus attract more trucks with origins or destinations within the corridor.

6.2.8. Step Eight: Determine the Financing Mechanism

How much of the capital cost of TOT lanes can be recovered from toll revenues is a financial challenge to transportation agencies, particularly for building regional and statewide TOT networks. Raising fuel tax rates or levying additional taxes to finance the development of TOT lanes might be opposed by the trucking industry and the general public. Public-private partnerships (PPPs) provide a financing opportunity to implement TOT lanes. However, the toll revenues generated from such a facility must be great enough to provide a desired rate of return to the private investors. In some cases, for example, where truck volumes are at the margin with respect to profitability, the toll rates would have to be high to generate sufficient revenues. High toll rates, of course, would be strongly opposed by the trucking industry.

6.2.9. Step Nine: Compare and Identify Priority TOT Corridors

The final step is to determine the priority ranking of building TOT corridors based on the defined goals, objectives, or performance measures. The identification of priority TOT corridors is an iterative process until a corridor with the desired level of performance is determined. Various desired performance measures will cause different results of priority TOT corridors. Due to the budgetary constraints for implementing TOT corridor candidates simultaneously, a multiple criteria decision making method is employed to determine the TOT corridor prioritization in a TOT lane network based on their ordinal ranking. Five categories in the ordinal scale including "poor", "fair", "good", "very good", and "excellent" are represented by numeric values of 1, 2, 3, 4, and 5 respectively. Numeric values are assigned to associated performance measures of each TOT corridor based on the evaluation of measurement scale. Weights for each performance measure are dependent on their relative importance in the agency decision. The total score of each TOT corridor is calculated as follows:

Total score = $\sum$ (Weights $\times$ Numeric values).

TOT corridors with a higher total score should have a higher priority to implement first. Table 6-1 shows an example of multiple criteria decision matrix for the TOT corridor prioritization. In this example, a higher weight is assigned to the performance of revenue generation and the highest numeric value is given to the promising corridor B that could raise more toll revenues.

Table 6-1: Example of Decision Matrix for TOT Corridor Prioritization

Weights	Multiple Criteria	Numeric Values of Ordinal Scale		
	Performance Measures	Corridors A	Corridors B	Corridors C
3.0	Revenue generation	2	5	3
2.0	Travel time savings (or delays) on TOT lanes	2	5	3
2.0	Improved level of service on GP lanes	2	5	3
1.0	Improved level of service on local roads	2	5	3
2.0	Safety improvement (Locations of high truck-related crashes)	2	4	2
1.0	Available right of way	5	2	3
1.0	Minimum construction impacts to HOV lanes	5	2	3
2.0	The trucking industry's support	2	4	3
1.0	The general public's support	3	5	3
2.0	Private investors' incentives	2	3	2
	Total Score	41	71	47
	Priority Ranking	**3**	**1**	**2**

Notes:

1. The ordinal scale of five categories is represented by "poor"=1, "fair"=2, "good"=3, "very good"=4, and "excellent"= 5.
2. Total scores for each TOT corridor are computed from sum of weights multiplied by the numeric values of ordinal scale.
3. Weights are adjustable based on their importance in the decision process.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

This dissertation has focused on an analysis of TOT lane feasibility in the Atlanta and Georgia freeway networks. An ideal TOT lane should be able to provide benefits to the government by generating sufficient revenues to relieve itself of the burden of financing transportation infrastructure, to the trucking industry by providing travel time savings and reliable trips, and to the general public by improving traffic conditions and reducing truck-car crashes. A GIS-based analysis was used as a screening method to identify potential TOT corridors, and then the ARC travel demand model was used to derive performance measures for building TOT lanes in individual corridors and on the regional network. Various modeling scenarios of adding general purpose lanes and building mandatory or voluntary TOT lanes were assessed and compared based on their performance measures. The methodology for assessing the feasibility of TOT lanes at different scales was developed and resulted in the identification of TOT lane segments that appeared reasonable for the Georgia context. The methodology suggests that TOT lanes can be implemented in a metropolitan area such as the metro Atlanta area. The value of this dissertation and the recommendations for future research are addressed as follows.

7.1. Contributions and Findings

7.1.1. Contributions

The major contributions of this dissertation are as follows:

- This research identified key factors and variables that affect the feasibility of TOT lanes, such as trucker's willingness-to-pay, tolling policy, TOT lane utilization, truck diversion, and percentage of through truck tips.

- This research developed a methodology for identifying candidate TOT lanes and applied it to an individual corridor, a regional network, and a statewide system. This methodology is applicable to other metropolitan areas and states. In particular, the concept of a trucker's cost savings threshold applied to determine feasible TOT corridors and their extent or boundary is first used by this research.
- This research assessed the placement of TOT lanes whether in the inside or outside lanes based on the percentage of through truck volumes, available right of way, and the potential need to relocate existing HOV lanes. According to the distribution of through truck volume percentage in the Atlanta freeway system and the locations of the largest warehouses and distribution centers along each corridor, the research recommended specific boundaries of more than 50% and less than 30% of through truck volumes for engineers to consider building inside and outside TOT lanes.
- This research proposed the optimum toll rates on TOT lanes based on the potential to generate maximum revenues, maintain an acceptable level of service at least C or D, encourage a utilization rate of at least 50% to justify investments in TOT lanes and improvements in general purpose lanes, and create a truck diversion rate from local roadways to TOT lanes to improve local traffic congestion and truck accidents.
- This research illustrated the tradeoffs that are associated with different toll policies (mandatory or voluntary) and the relationships among key variables that were determined from a network model application to the Atlanta freeway network.
- This research generalized specific results to the transportation community and developed planning guidance for TOT lanes.

7.1.2. Findings

Research findings from the modeling of TOT lanes in different geographic applications are as follows:

- The screening criteria of the methodology can be applied to other states, but the threshold values might be different. For example, a metropolitan area with a high percentage of through truck traffic (external-to-external) will be different from an area with a high percentage of local truck traffic (internal-to-internal or internal-to-external). These different truck trip characteristics will influence the target of serving local truck or through truck traffic, locations of access points, and the number of TOT lanes.
- Sensitivity analysis of different levels of truckers' willingness to pay showed large differences in the resulting feasibility of TOT lane corridors. For example, more potential TOT lanes were selected from the criterion of 90% truckers' cost saving threshold than the criterion of 50% truckers' cost saving threshold.
- Local trucks might not use a TOT lane if interchanges/ramps are not provided along the corridor, because they need to ship freight to warehouses and distribution centers located within the corridor. Nevertheless, freight movement traveling through a corridor without stopping to load or unload cargo will use this type of TOT lane. Due to the locations of major freight movement generators along the TOT corridors of I-75S, I-85S, and I-20W that have very low through truck trips, direct access ramps to connect with these large warehouses and distribution centers should be built to serve truck trips originating or terminating within these corridors.
- Even though TOT lanes can provide travel time savings, some trucks would not use the TOT lanes and would choose parallel roads to avoid a toll cost. This means that trucks would not actually behave the way they are being modeled. This problem may originate from the stated preference surveys of truckers' willingness-to-pay. Usually most truckers will answer the hypothetical choices honestly, but sometimes they may not because they try to influence the decision of adopting a toll policy. For example, even if toll rates are very low; the survey result shows that some truckers are still unwilling to use TOT lanes.

- The diversion of truck traffic to local roads will cause traffic congestion and more accidents on those roads. The ARC travel demand model can evaluate truck traffic that diverts to alternative parallel arterials for a TOT corridor within the 20-county area of the Atlanta interstate system. However, truck trips outside the Atlanta region cannot be assigned to other facility types of arterial and local roads. Therefore, the level of detail on truck diversion for statewide application is limited.
- One of the significant challenges facing truck-only lanes in the determination of where the financing will come from to build and operate the facility. The transportation profession has shown great interest in the use of public-private partnerships for such finance. However, the motivation of private financiers will be directly tied to the expected return on investment. This return on investment will be related to how many trucks actually use the truck lanes. This research has shown the trade-offs associated with mandatory and voluntary use of TOT lanes, and the resulting consequences on freeway performance. This issue of mandatory versus voluntary use of TOT lanes could be one of the most challenging decisions facing state DOTs that are contemplating such lanes.

7.1.3. Limitations

The limitations of this research include the following:

- Truck classification counts used to validate highway link truck volumes in the ARC travel demand model must be improved. Due to insufficient truck count data from GDOT's automatic traffic recorder (ATR) and portable traffic count database, data collection of truck counts in the Atlanta interstate system should be conducted to refine the model's forecast accuracy.
- Medium-sized truck drivers' values of time have not been estimated from the stated preference surveys of truckers' willingness to pay, which might cause toll revenues being overestimated by assuming they are equal to heavy truckers' values of time.

The modeling results will be inappropriate for urban areas with large amounts of pickup and delivery service by medium trucks.

- A statewide travel demand model provides the benefits of forecasting long distance truck trips and external-to-external through truck trips outside a metropolitan area. However, the statewide model is constrained in the modeling of local freight route choices and short distance truck trips originating and terminating within the same county.

7.2. Recommendations for Future Research

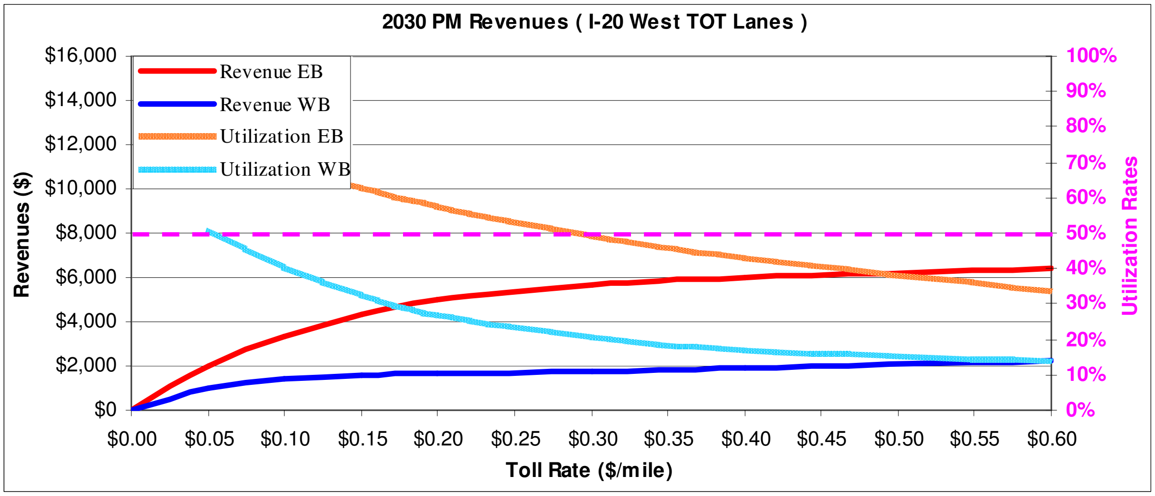
Future research may include:

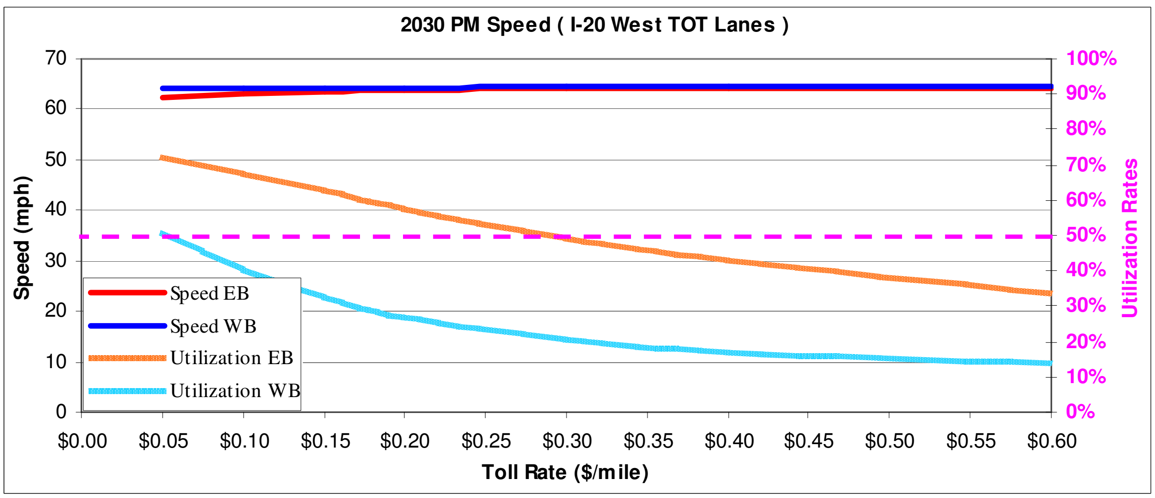
- The process of identifying potential TOT lanes assumed equal weight attached to each of the screening criteria. One could assign different weights to the criteria representing different values attached to the underlying benefit associated with each criterion. Additionally, one could also undertake a sensitivity analysis of this selection process to determine how many network links satisfied four of the five, three of the five, etc. screening criteria.
- In the ARC travel demand model, most TOT corridors might be coded with a default free-flow speed lower than the actual driving speed on the freeway. Therefore, modeling outputs might create a lower travel speed on TOT lanes. Future improvement in the model may consider coding a higher free flow speed and raising the speed limit on TOT lanes based on a survey of truck speed data collection.
- In Georgia, 79% of the freight tonnage shipped will be by truck, 20% by railroad, 0.6% by water, and 0.3% by air in 2035 without TOT lanes built (GDOT 2006). There is a need to examine the potential shift of freight traffic from railroad to TOT lanes under various toll policies and operational scenarios in the statewide TOT network.

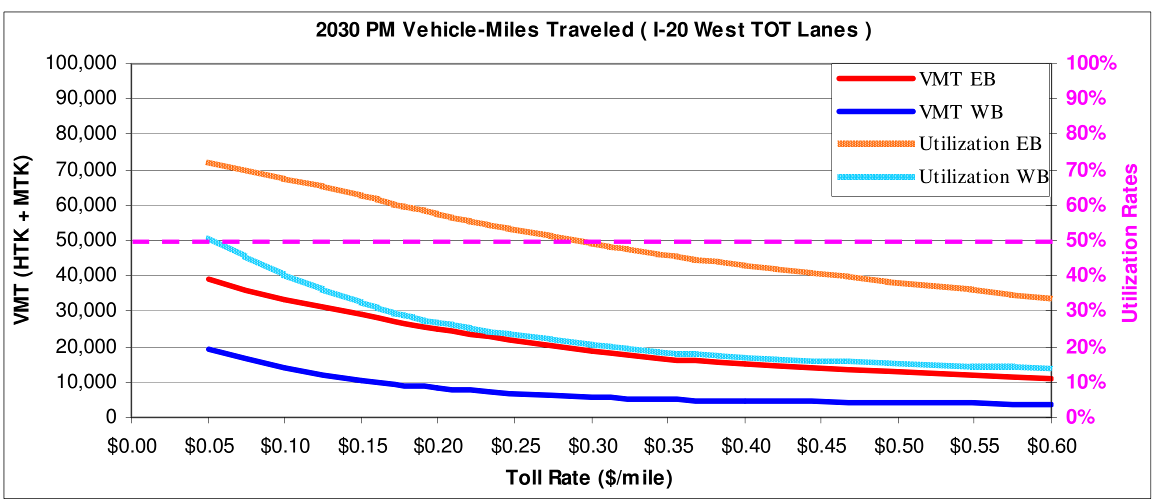
- Modeling truck trip reliability can be further developed by developing the buffer time, which is defined as the 95th percentile travel time minus the average travel time. Less buffer time means higher trip reliability. Currently, there are no existing TOT lanes to obtain continuous truck travel time data from and to develop the buffer time index as a measure of reliability. However, truck travel time data on existing GP lanes collected from the traffic monitoring center could be developed as a reliability function to estimate potential TOT lane buffer time.
- The change in truck vehicle-miles traveled (VMT) can be used to examine the improvement of air quality after building TOT lanes. ARC's emissions model or the U.S. environmental protection agency's (EPA's) vehicle emission modeling software "MOBILE6" and "MOVES" (MOtor Vehicle Emission Simulatorcan) can be used to estimate the emissions of hydrocarbons (HC), carbon monoxide (CO), nitrogen oxides (NOx), and particulate matter (PM) from trucks traveling on both general purpose lanes and TOT lanes.
- This research explored the implementation of TOT lanes in the Atlanta region, which handles a high percentage of through truck trips (external-to-external). Future research may examine the performances of areas with significant internal-to-external or external-to-internal truck trips such as a port city with heavy truck freight movements into and out of the port.
- The application of this research methodology to other states without their own statewide travel demand models would require certain modifications. Future research may focus on developing a prediction approach to forecast truck volumes and traffic congestion on interstate highways in the projected year, and then employing the screening process to identify potential TOT lanes.

APPENDIX A: Toll Rates, Revenues, Speed, and VMT in Atlanta TOT

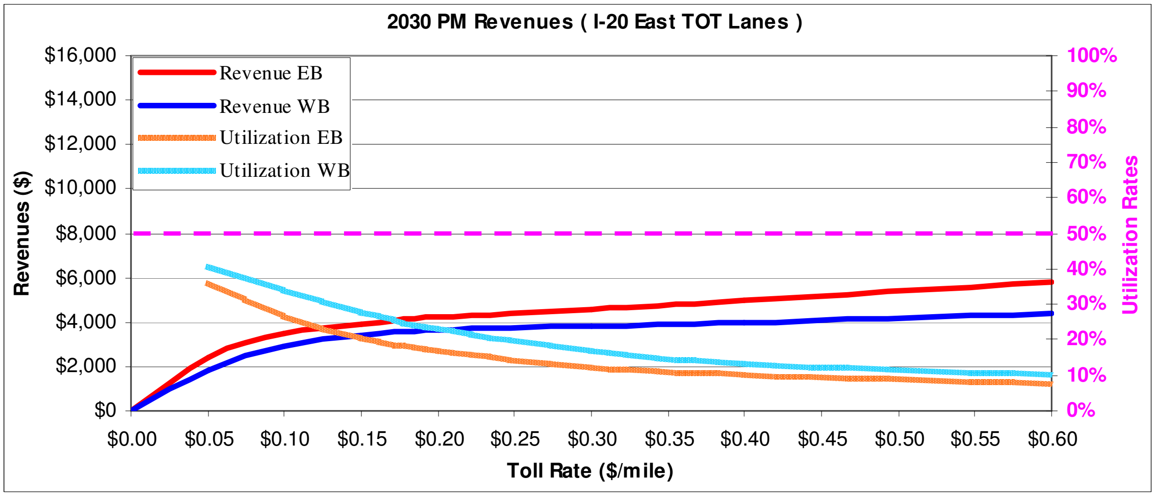
I-20 West (from I-285 West to Atlanta Regional Boundary in Carroll County)

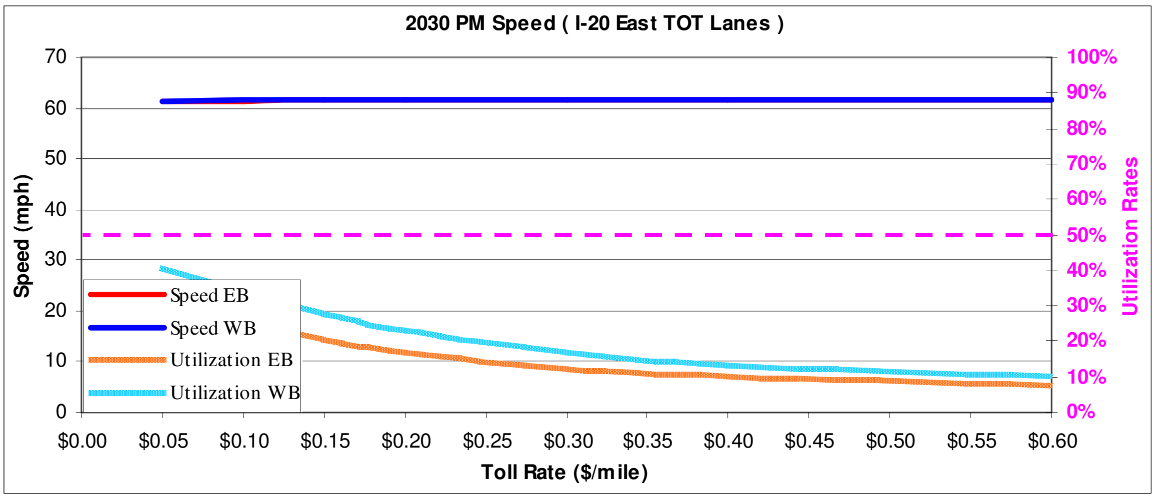


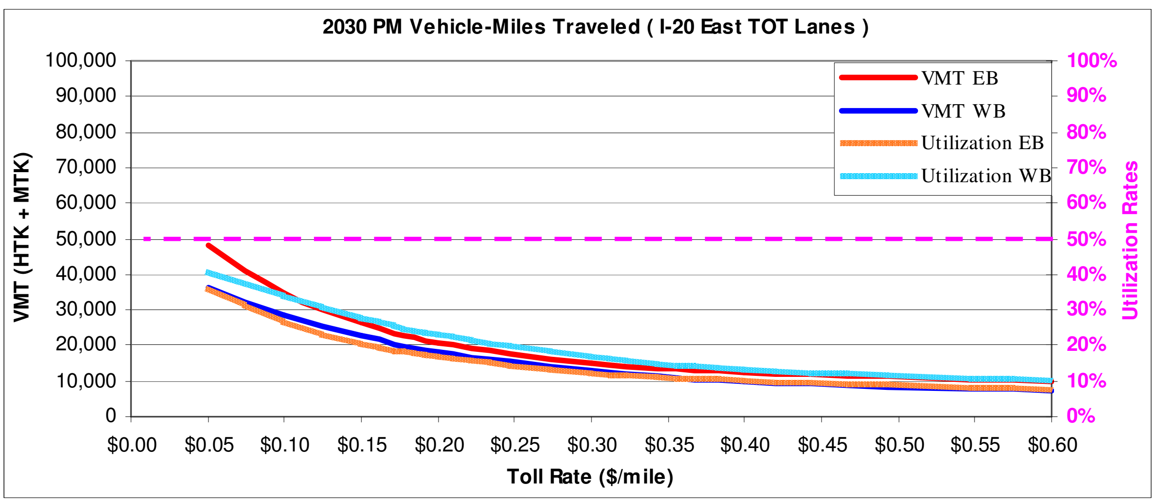




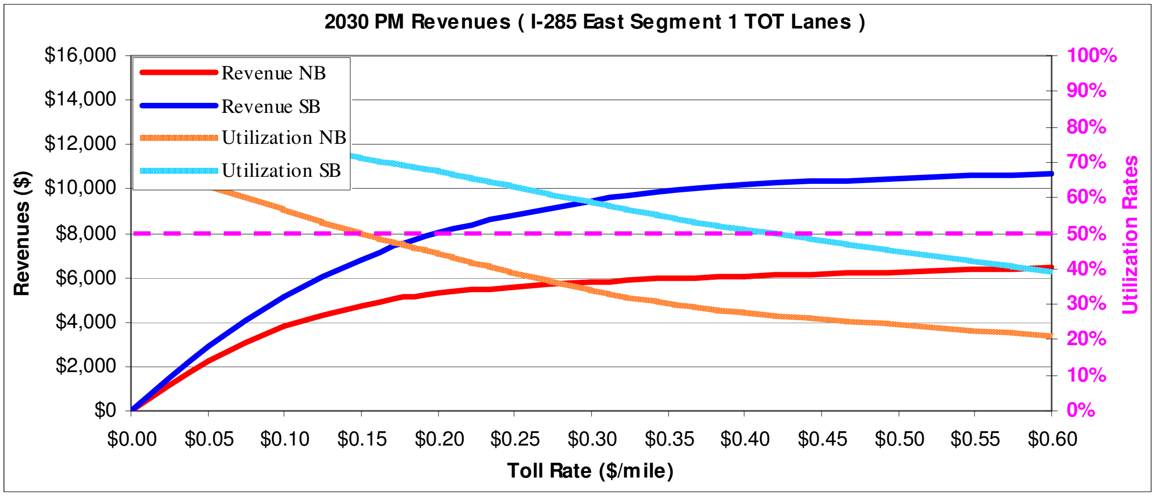
I-20 East (from I-285 East to SR 138 in Rockdale County)

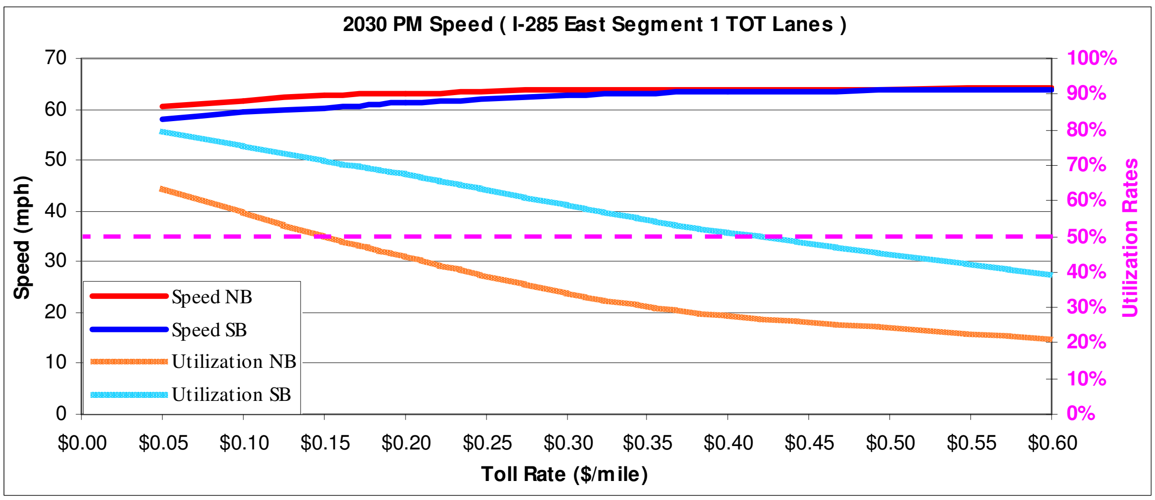


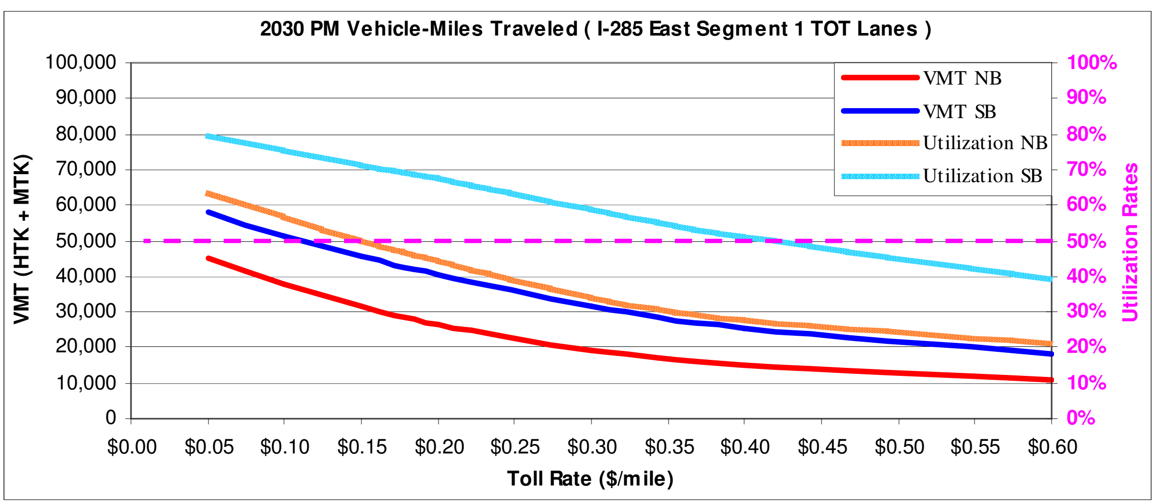




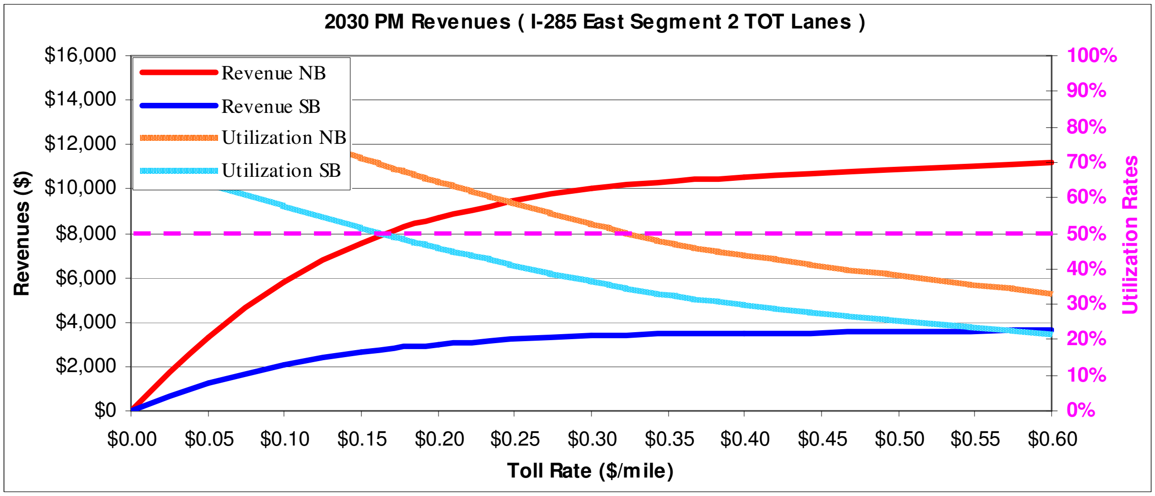
I-285 East Segment 1 (from I-85 North to I-20 East)

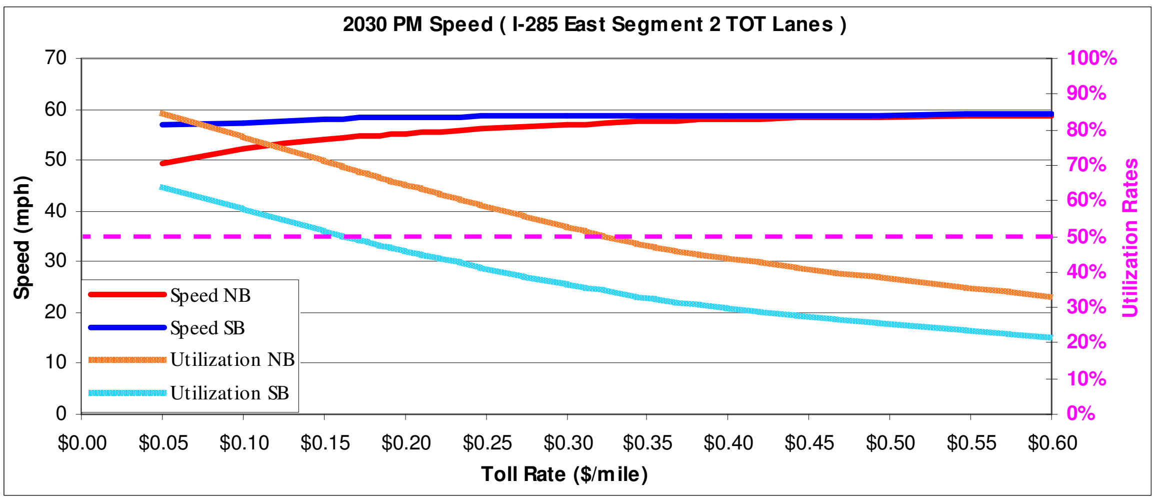


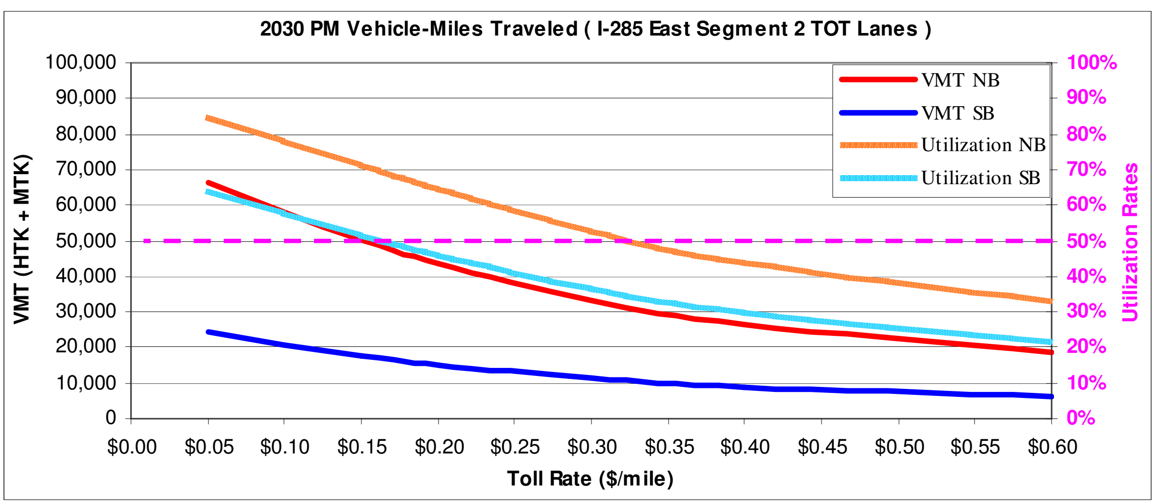




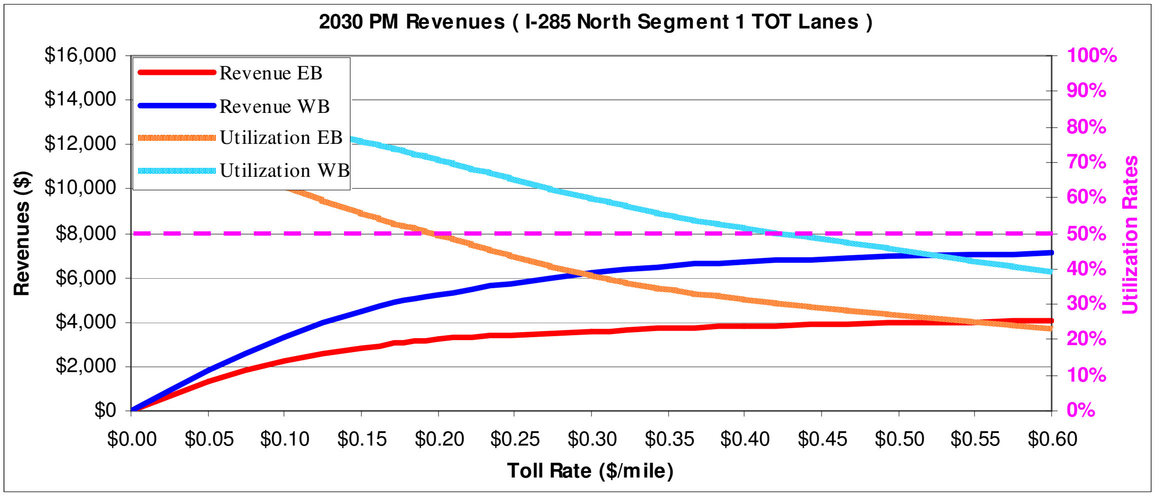
I-285 East Segment 2 (from I-20 East to I-75 South)

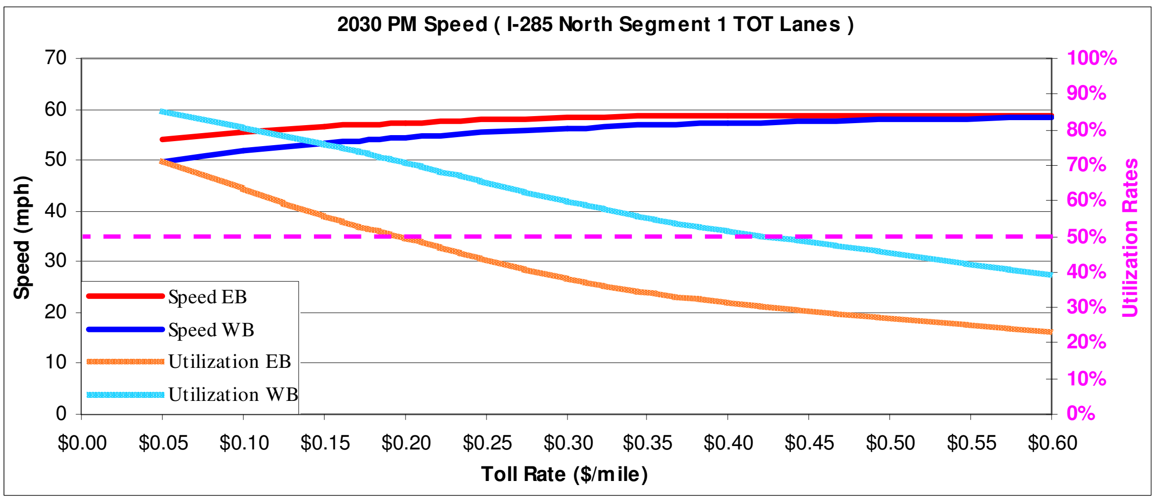


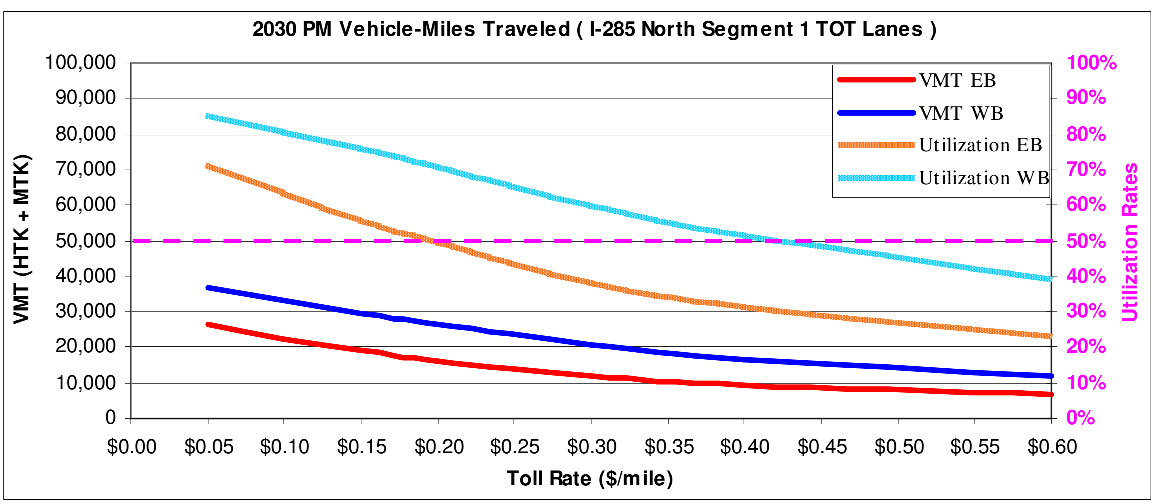




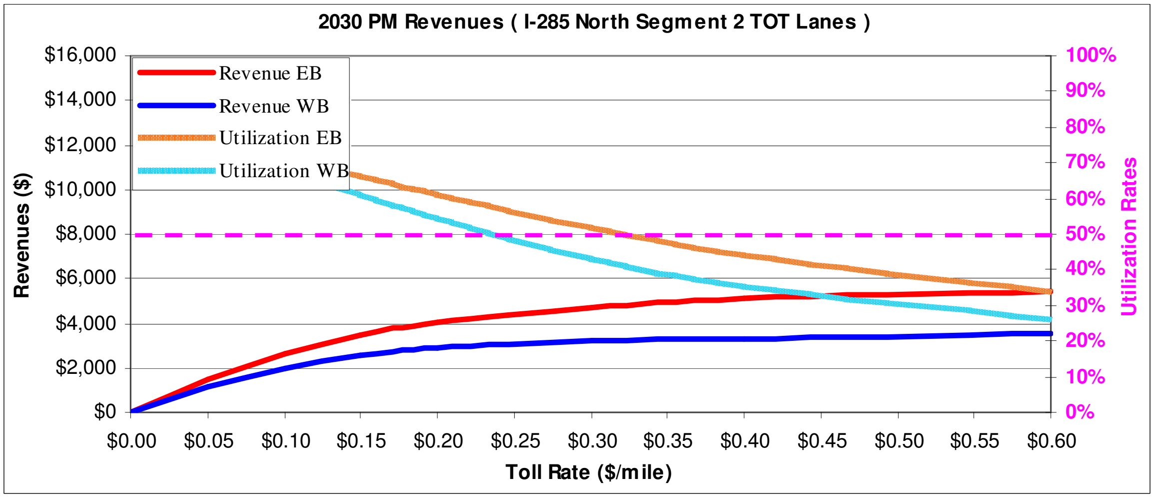
I-285 North Segment 1 (from I-75 North to GA 400)

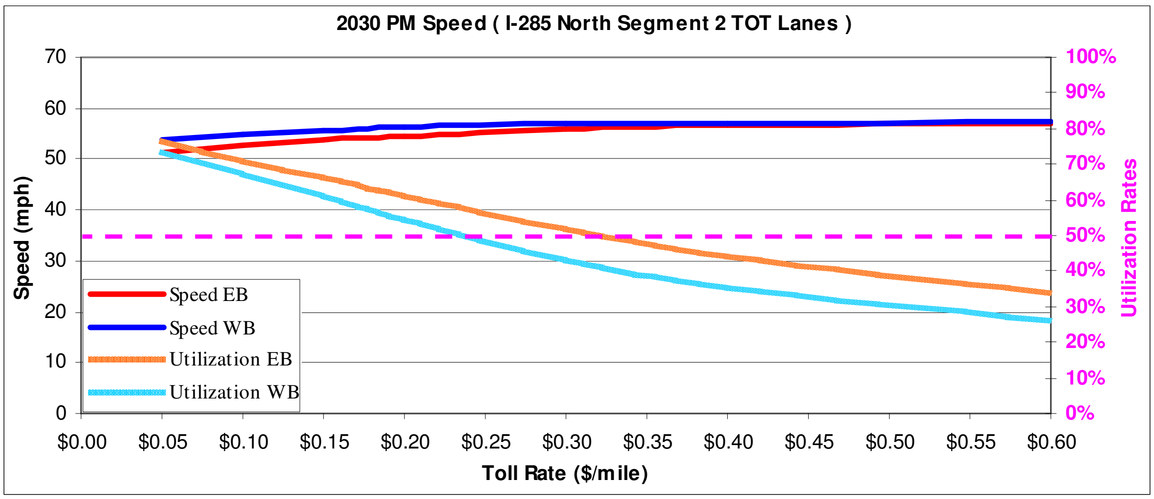


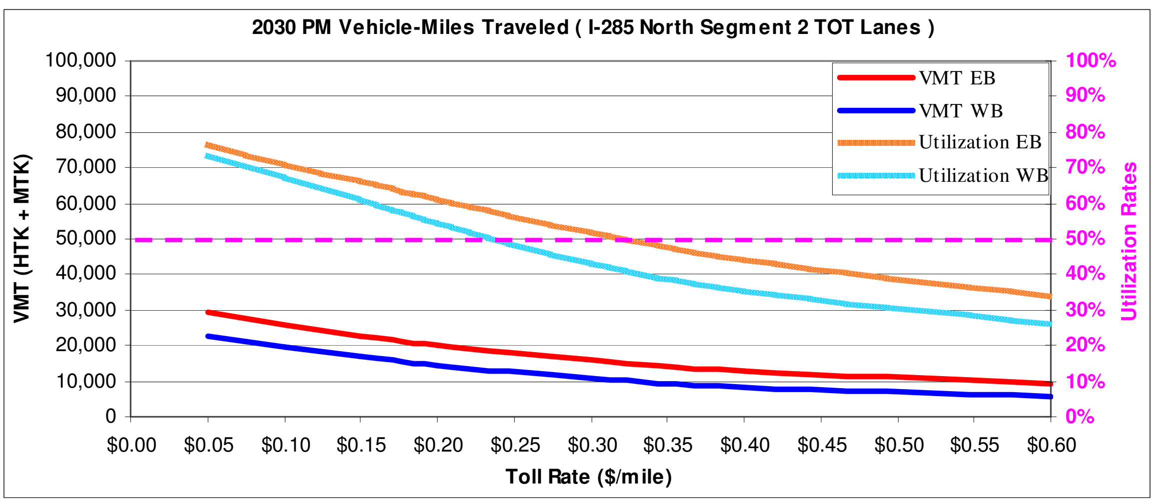




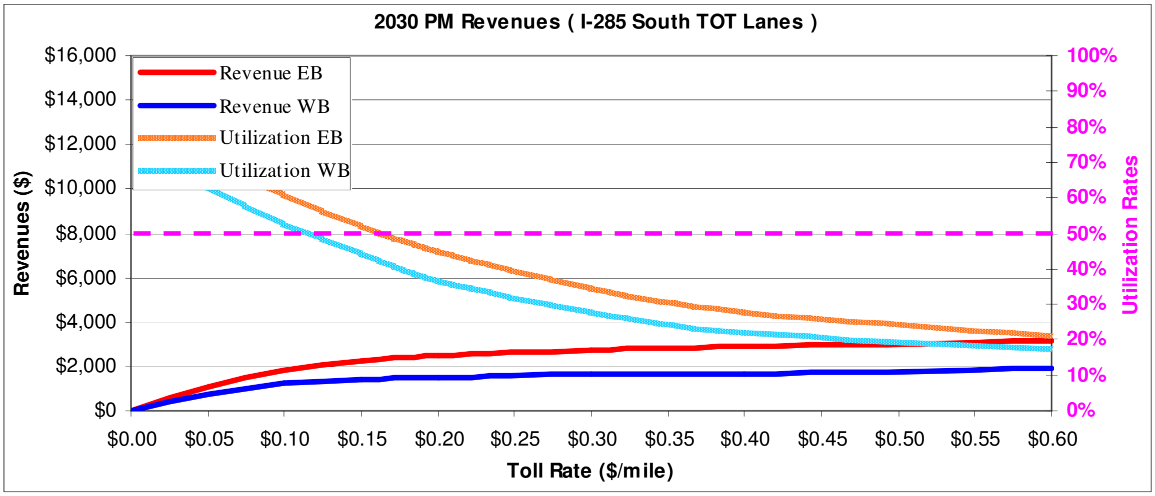
I-285 North Segment 2 (from GA 400 to I-85 North)

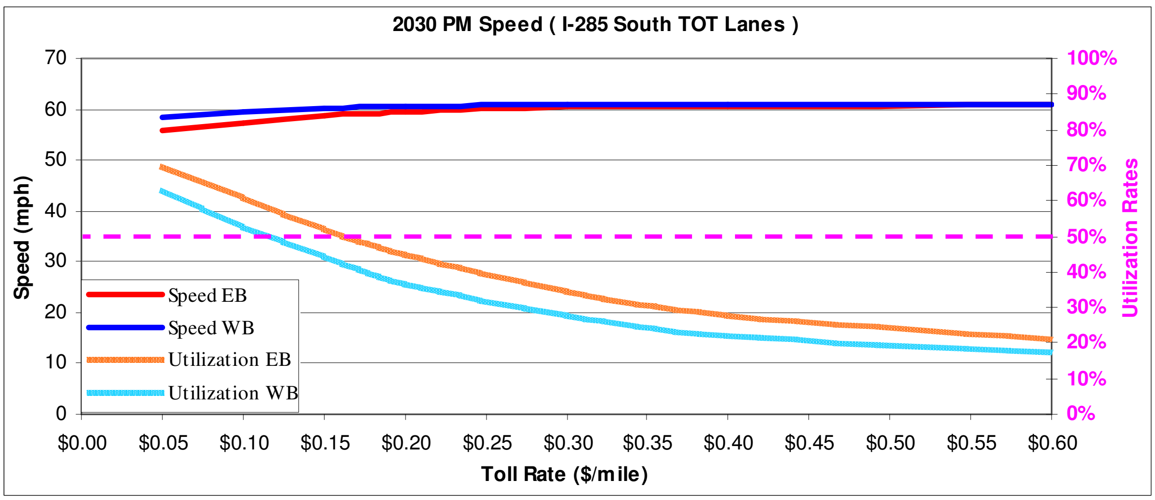


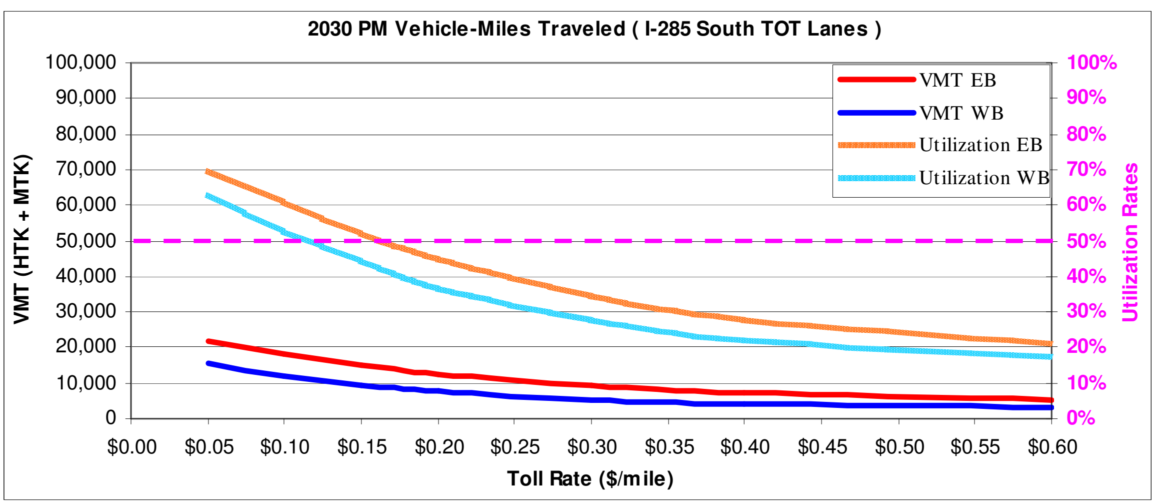




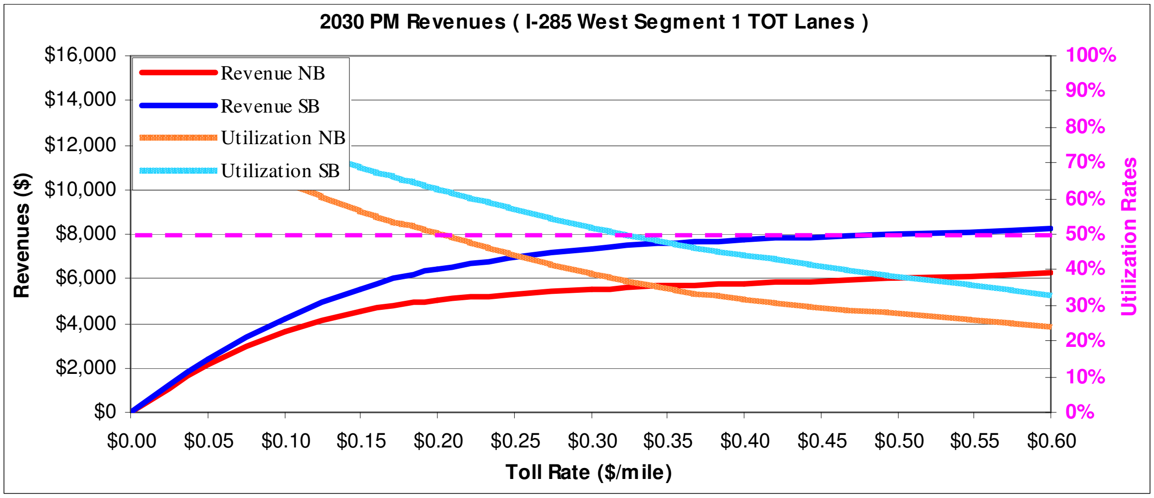
I-285 South (from I-75 South to I-85 South)

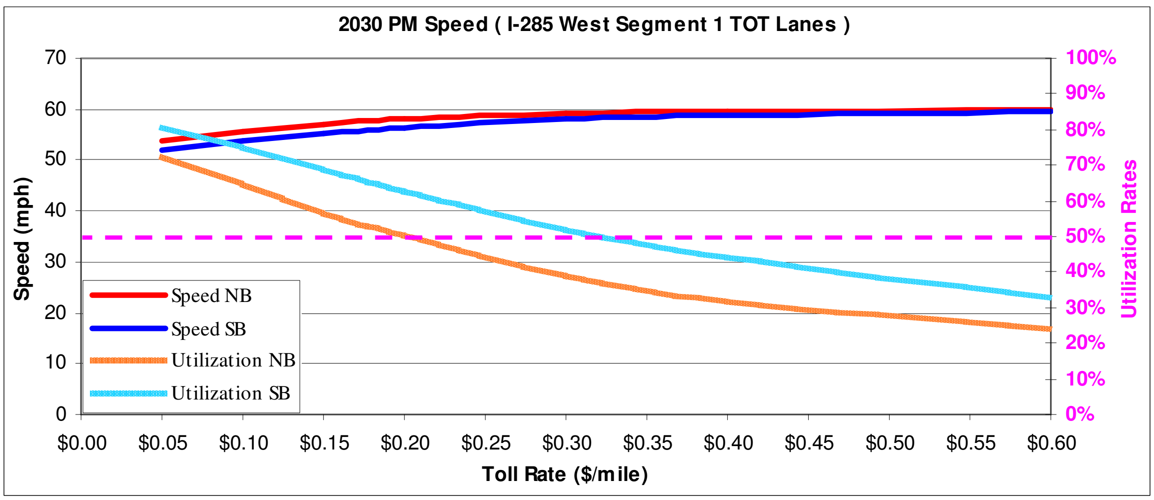


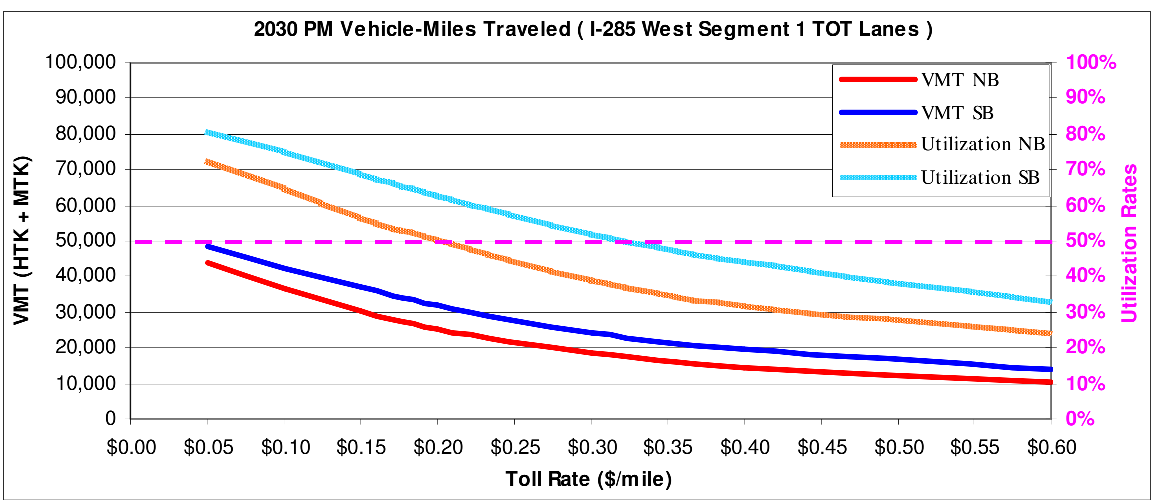




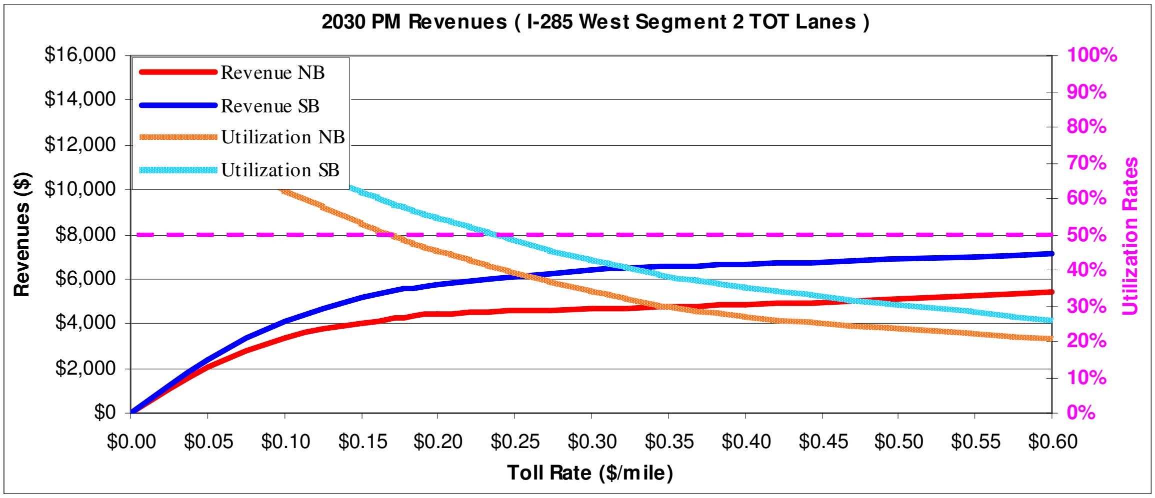
I-285 West Segment 1 (from I-75 North to I-20 West)

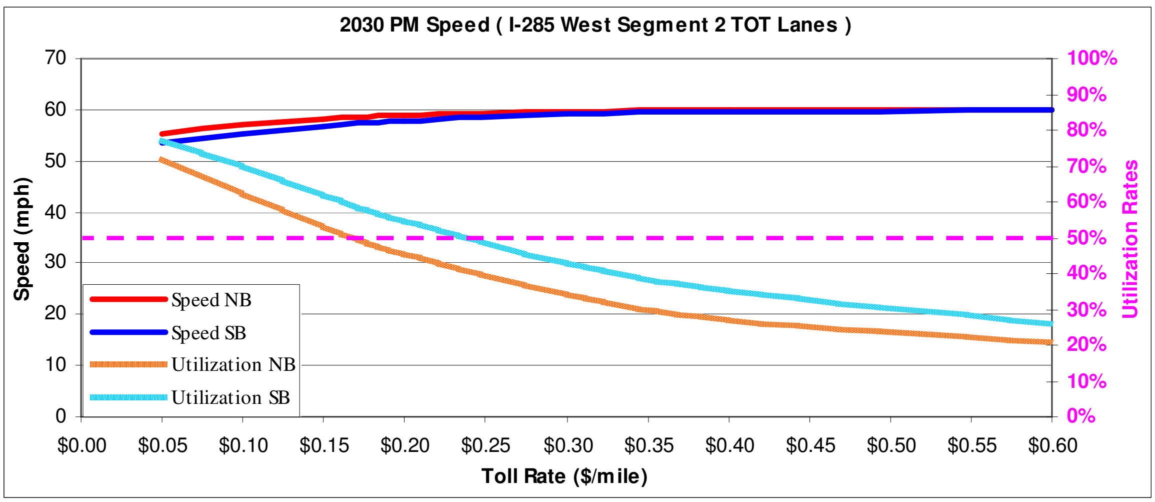


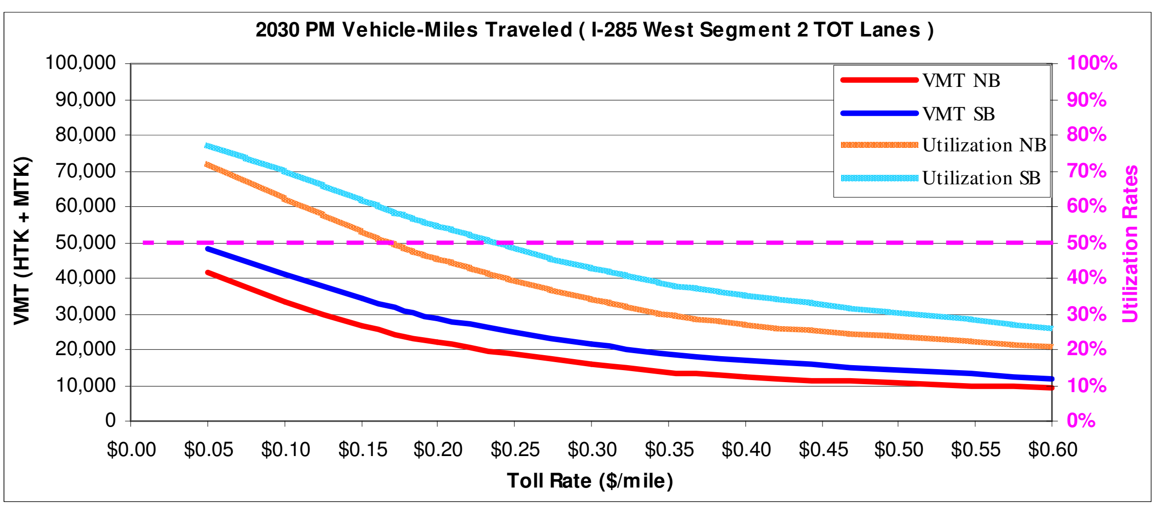




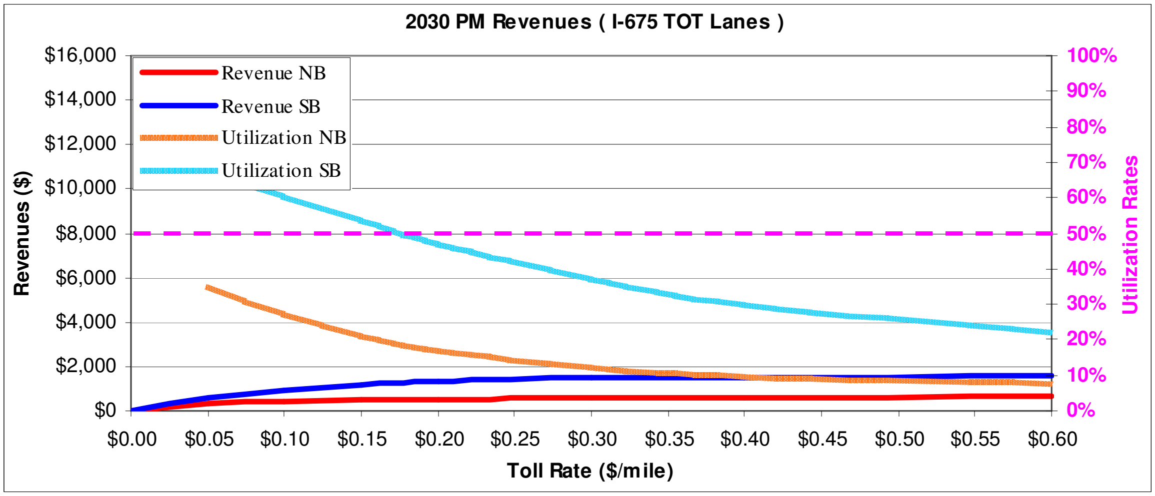
I-285 West Segment 2 (from I-20 West to I-85 South)

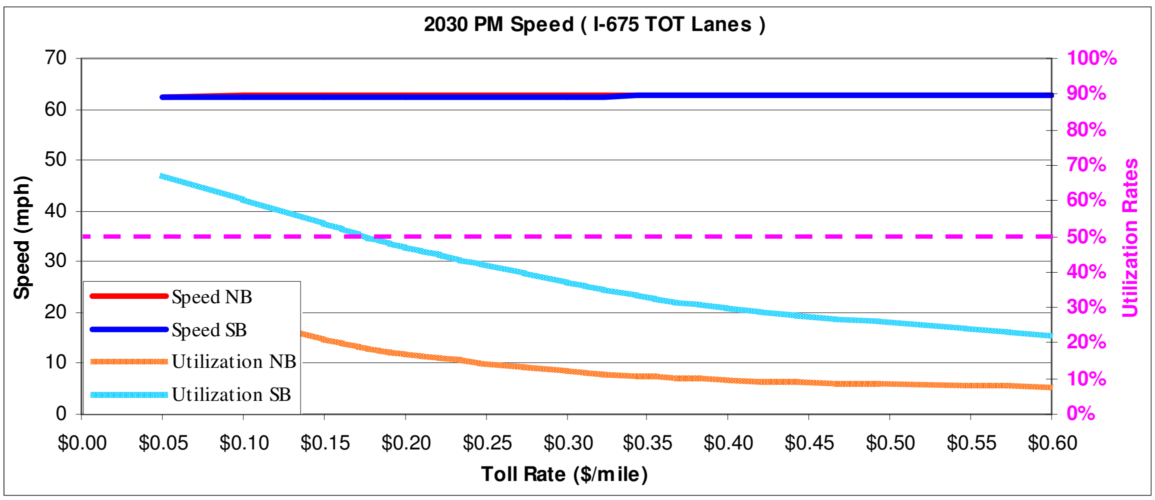


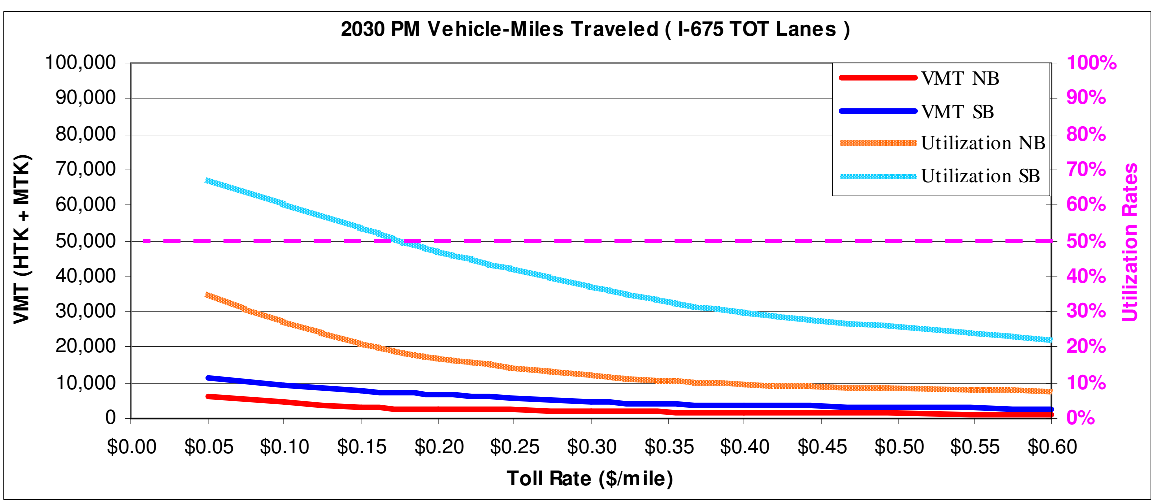




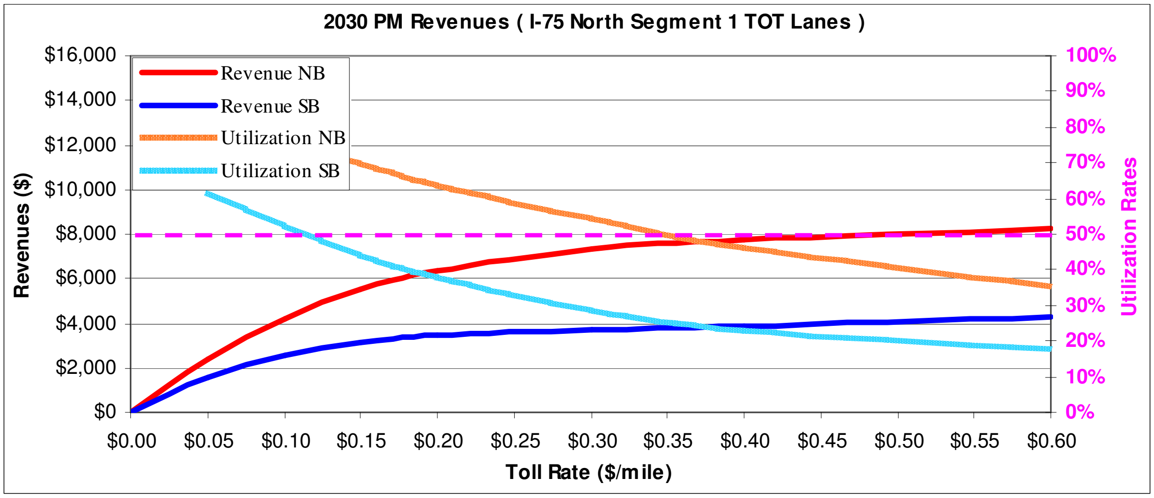
I-675 (from I-285 South to I-75 South)

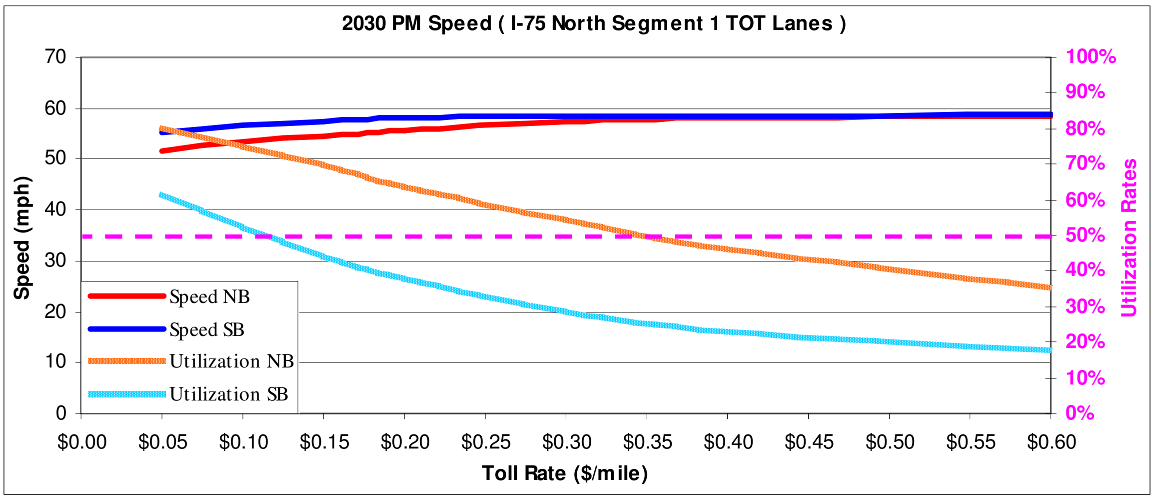


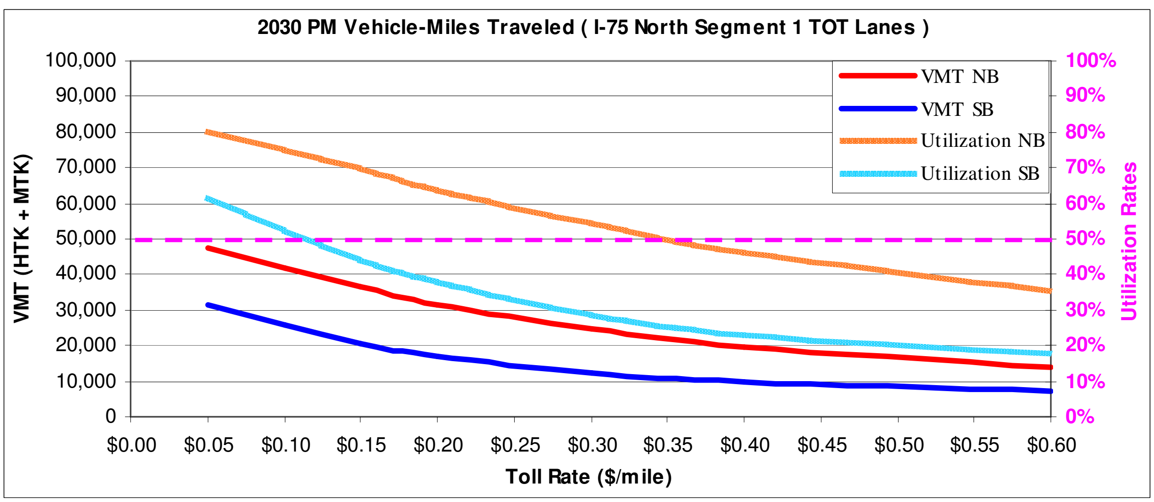




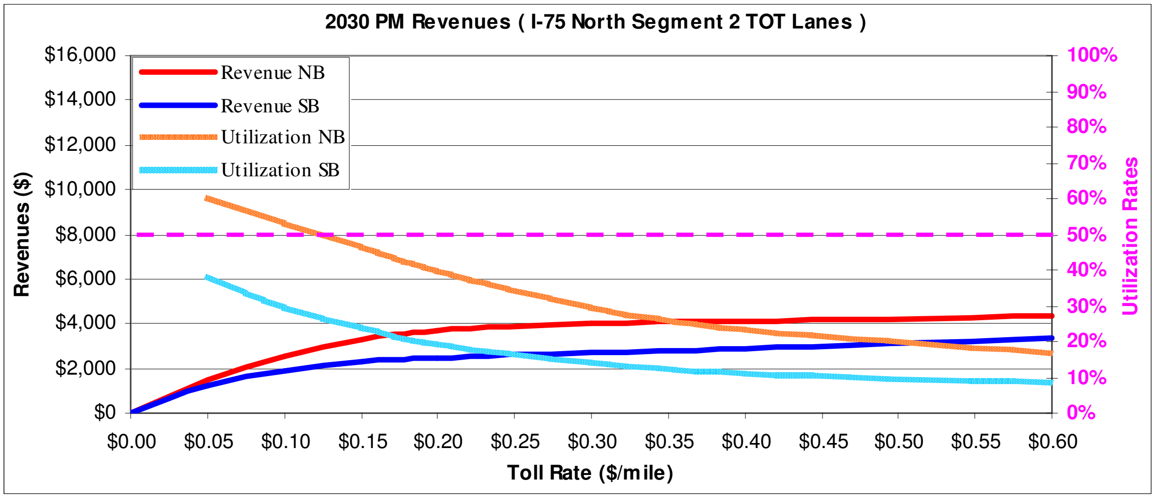
I-75 North Segment 1 (from I-285 North to I-575)

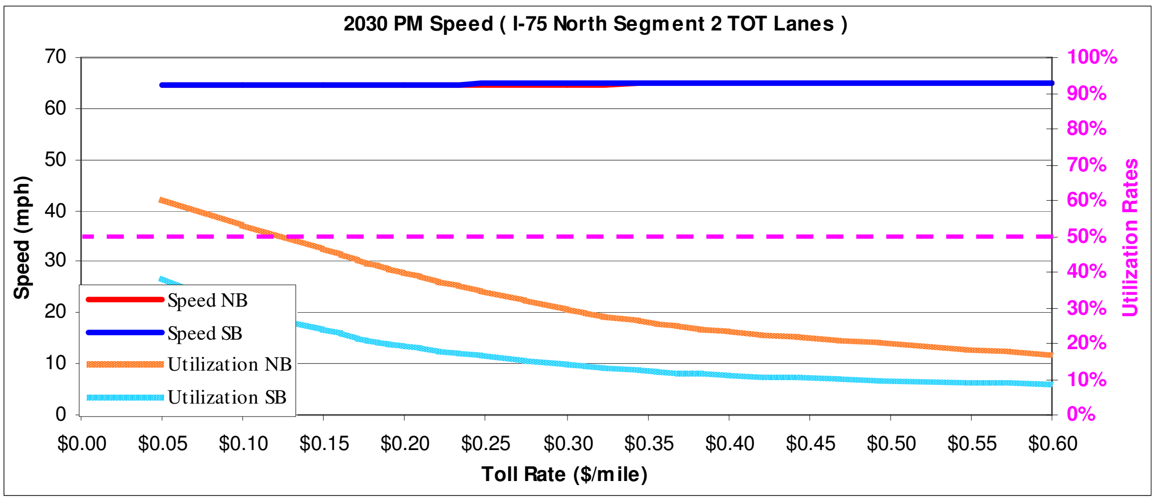


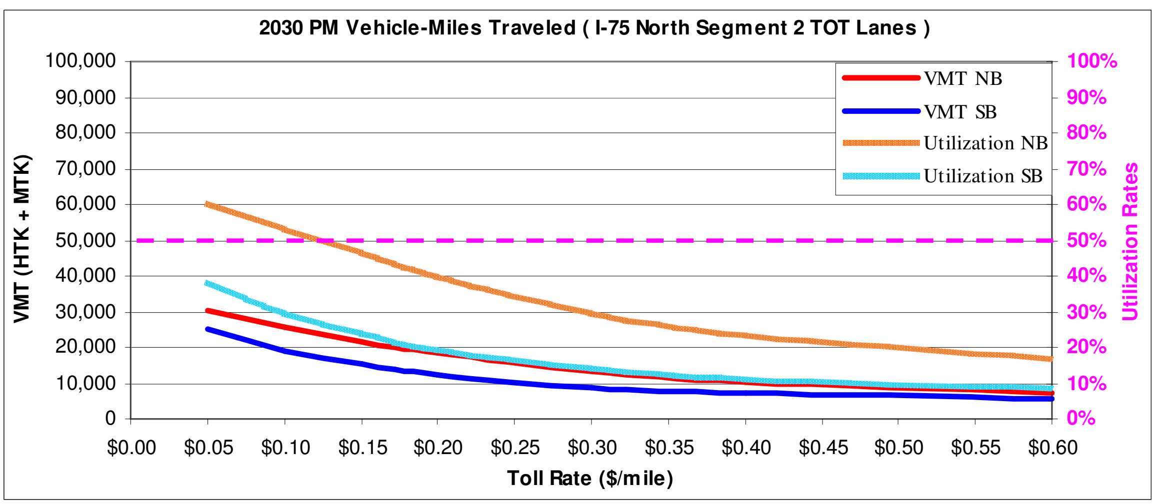




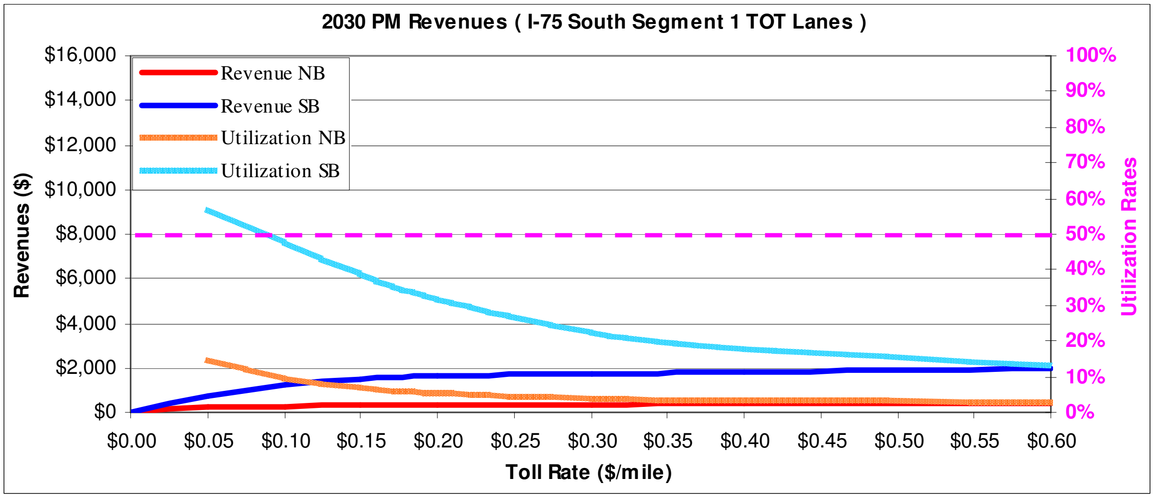
I-75 North Segment 2 (from I-575 to SR 20 in Bartow County)

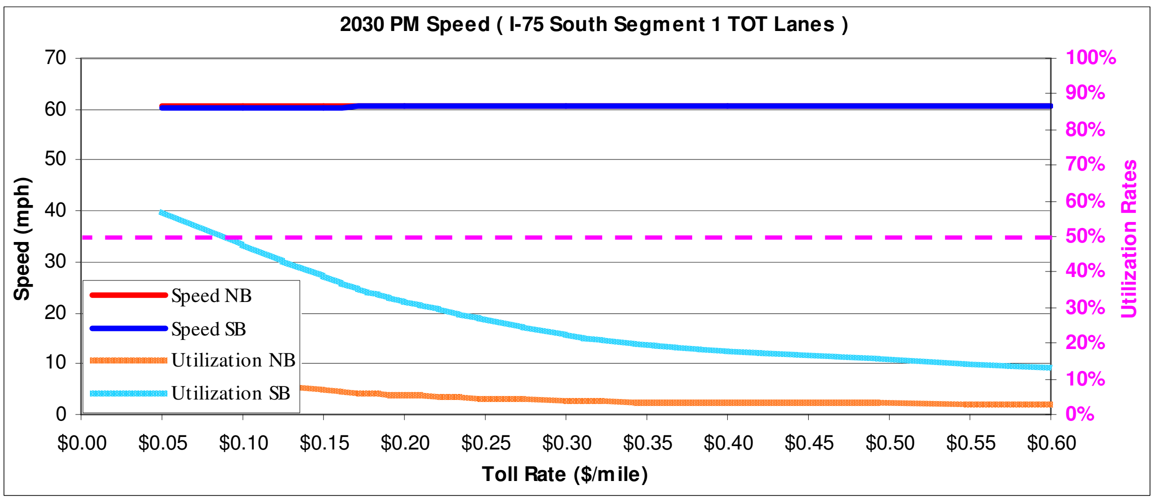


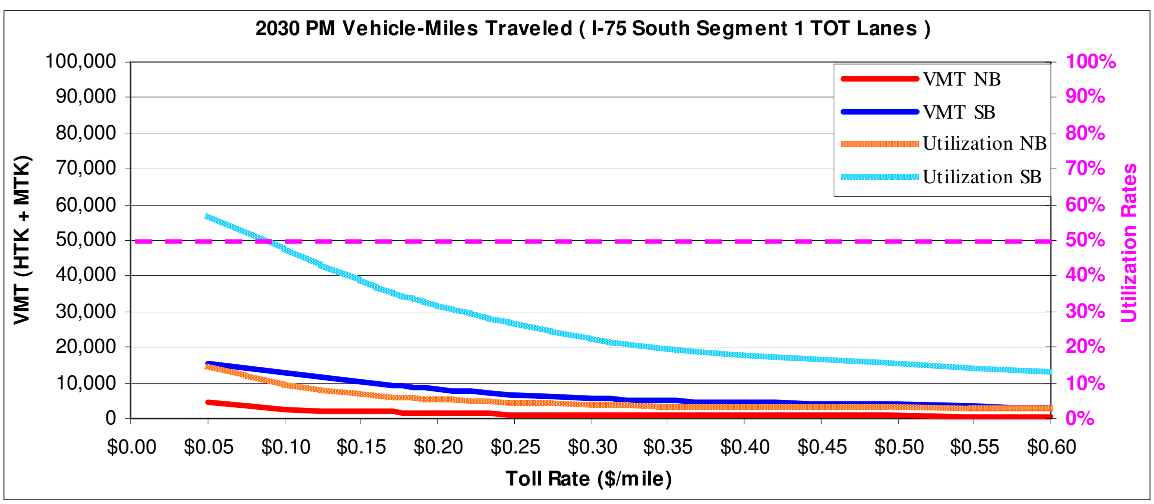




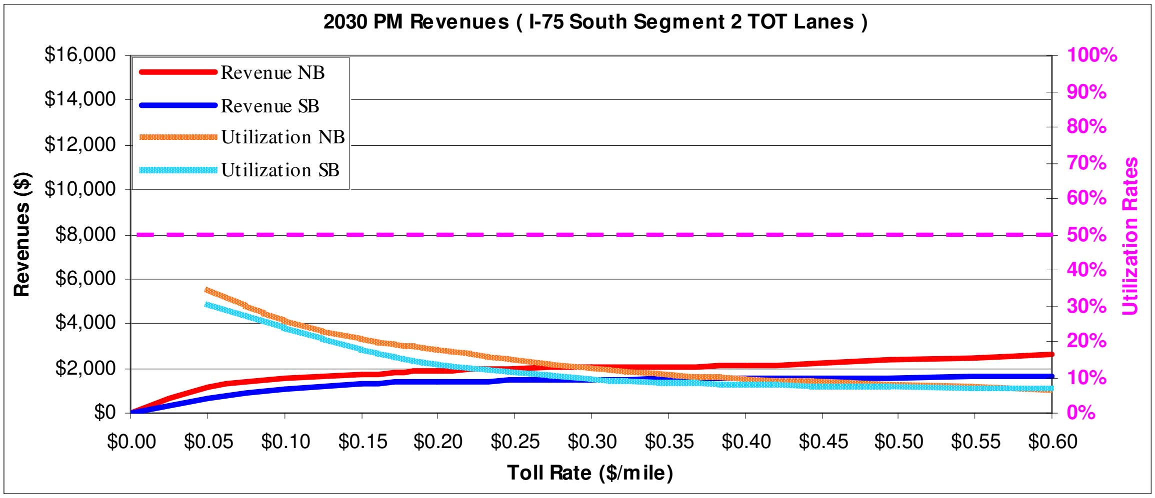
I-75 South Segment 1 (from I-285 South to I-675)

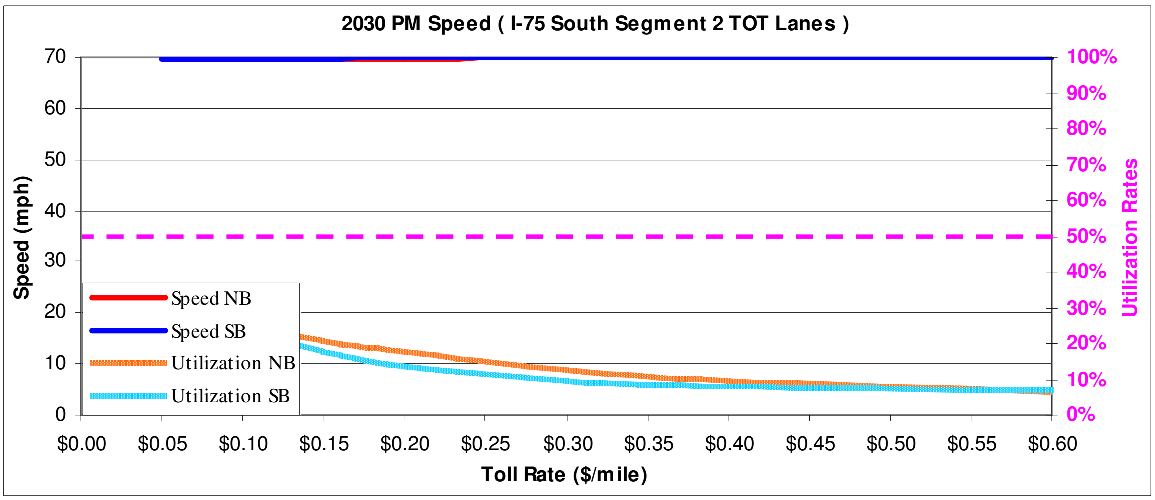


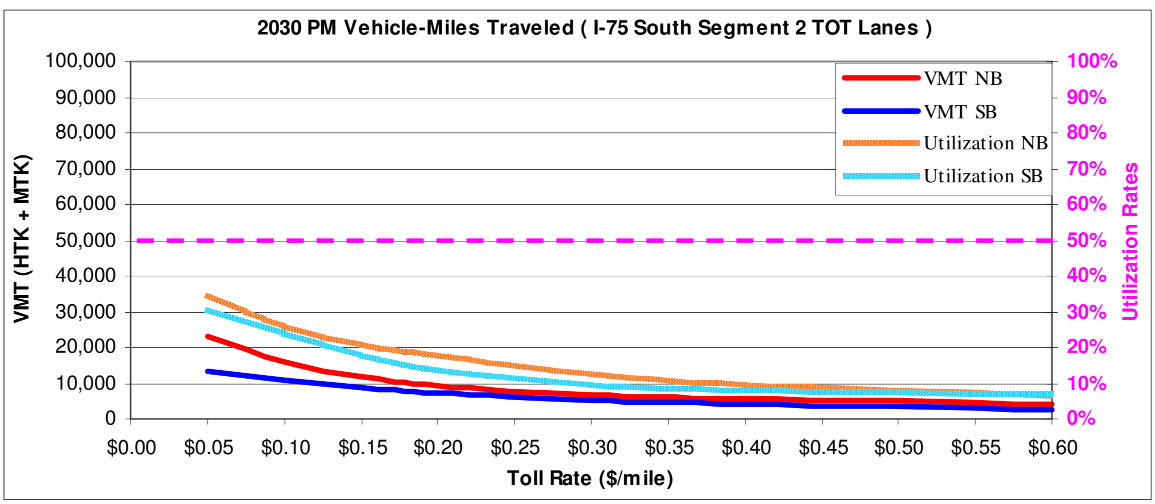




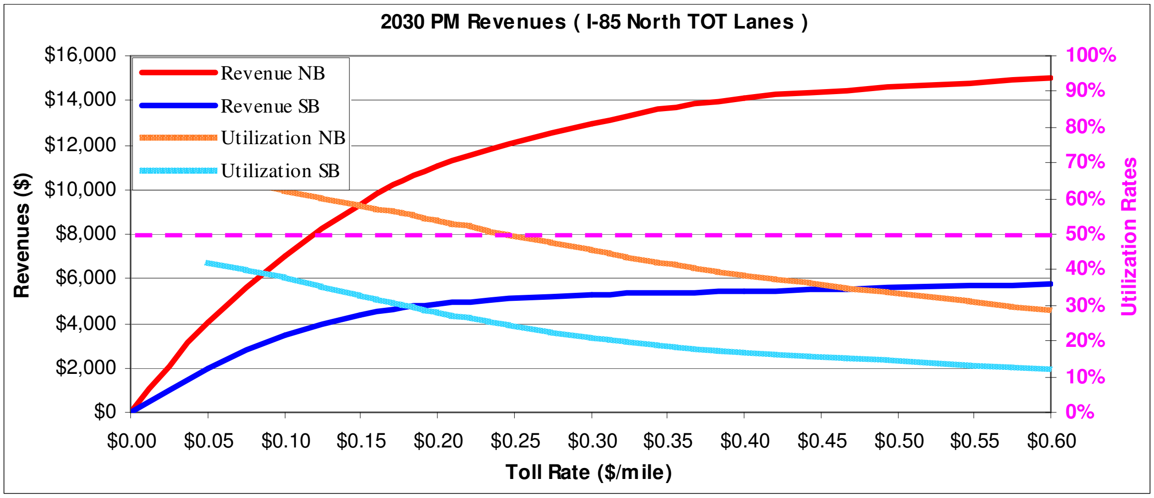
I-75 South Segment 2 (from I-675 to Atlanta Regional Boundary in Spalding County)

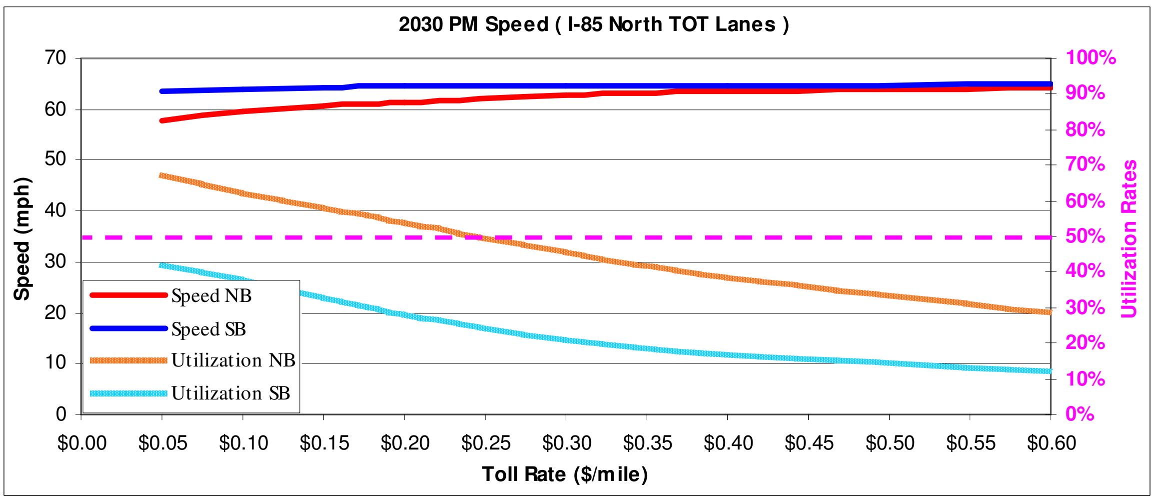


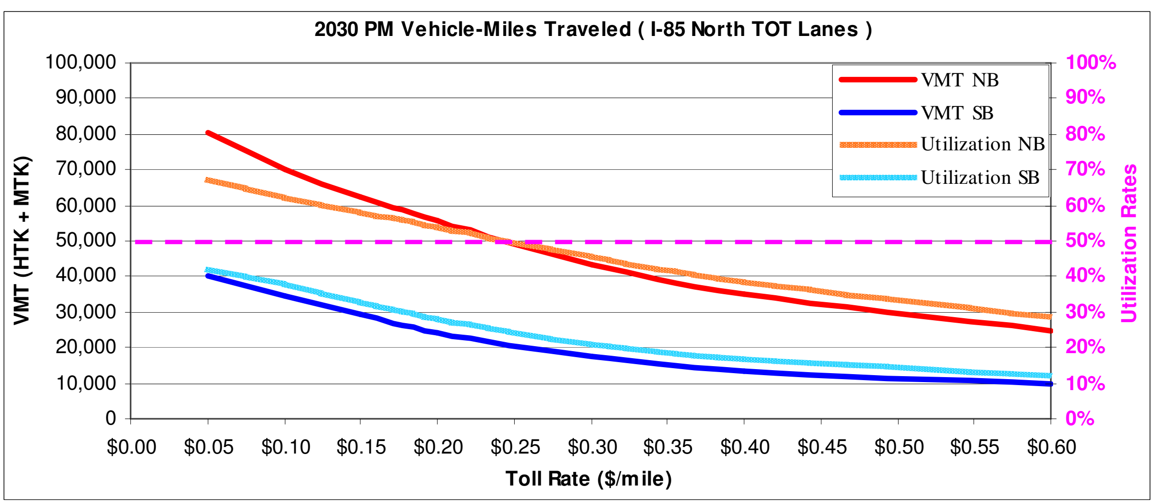




I-85 North (from I-285 North to I-985 in Gwinnett County)







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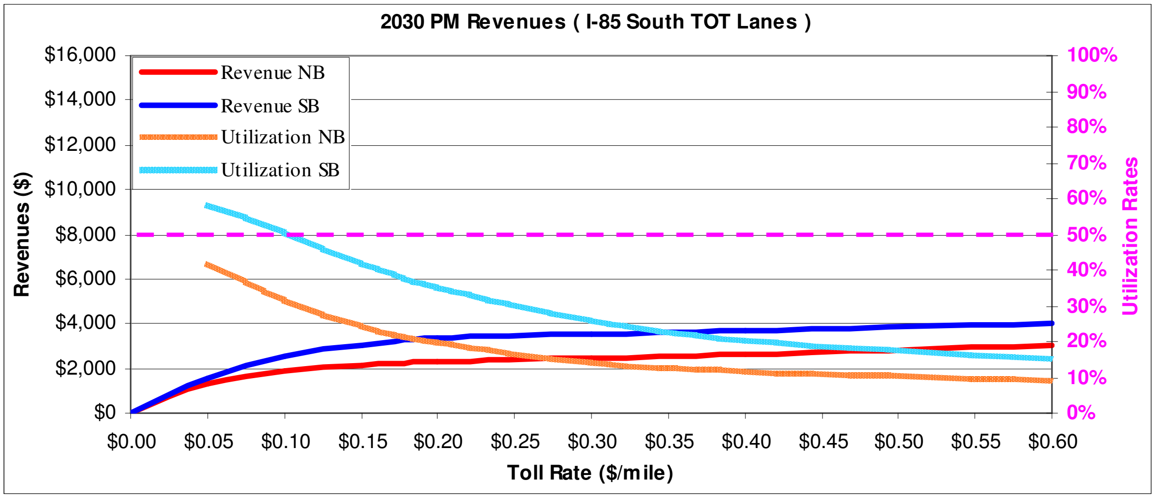

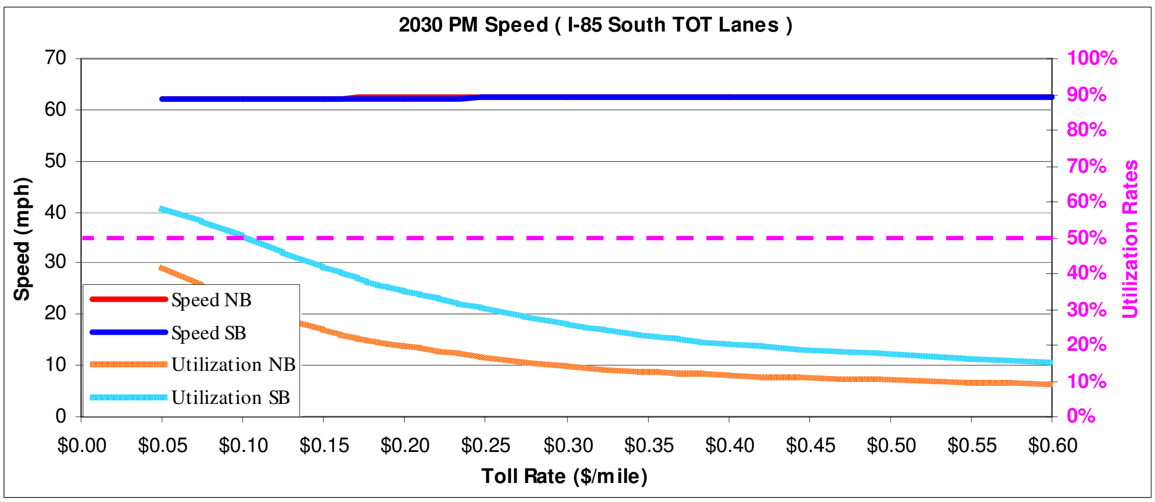

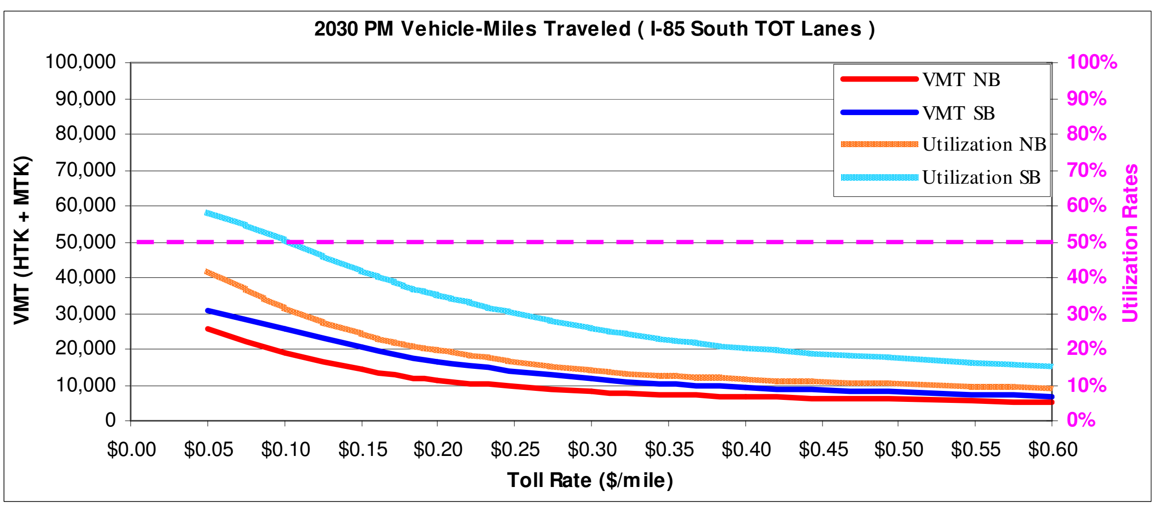

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